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ARBORS AND WORK HOLDING DEVICES

A TREATISE ON THE APPLIANCES USED FOR HOLDING WORK FOR TURNING, BORING AND GRINDING

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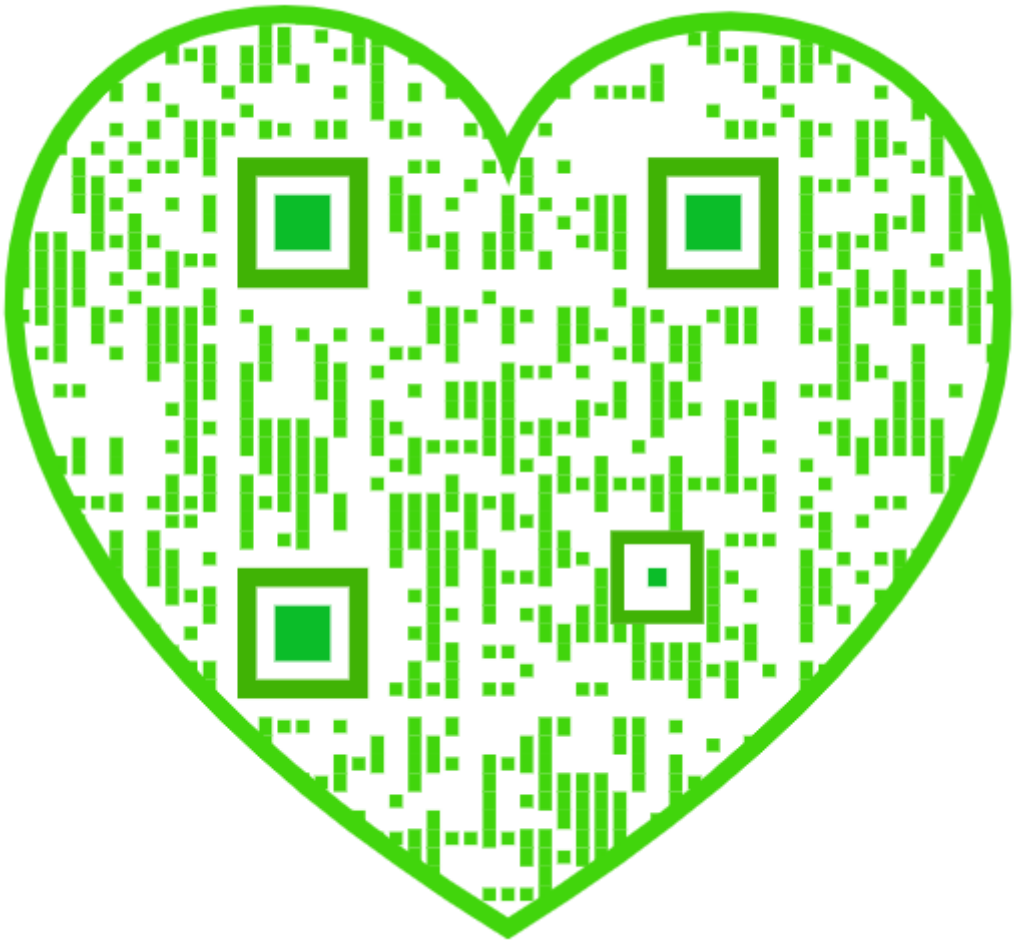

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NUMBER 120

ARBORS AND WORK-HOLDING DEVICES

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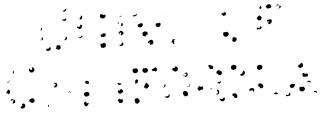

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CHAPTER I

HOLDING DEVICES FOR FIRST-OPERATION WORK

The methods of holding and clamping rough castings for the first or chucking "operation" are so diversified that the subject must, necessarily, be treated by means of examples representing different varieties of work. Nearly all of the examples shown are more or less cylindrical in shape, for the reason that elliptical, rectangular, or odd-shaped parts require special treatment and, therefore, can only be touched upon in an article of this kind. In the general course of manufacturing, there are occasionally pieces of peculiar shape which require chucking fixtures, but as this work is of such great variety, it is difficult to give much information regarding its handling except in a general way. Any piece of work of peculiar shape requires a thorough knowledge of the conditions governing its use, in order that it may be chucked properly and located from the surfaces which are of the greatest importance.

Important Points in Design of Chucking Devices

In the design and construction of chucking devices, there are a number of points to which the most careful consideration must be given. In some cases, the work must be held by the cored interior, as, for example, an automobile piston, or, in fact, any other work in which it is necessary to have an equal division of metal throughout the cylindrical walls. In other instances, however, some method of exterior holding may be perfectly satisfactory. The term "exterior holding" does not necessarily mean that chuck-jaws are referred to, for various devices other than jaws will be cited during the following discussion of holding methods.

Having determined whether the work is to be held externally or internally, let us take up the important points in the design of holding devices.

First: The important locating surfaces should be carefully considered, always having in mind the future handling of the piece in its various operations. Great care should be taken that no locating points are so placed that they will come in contact with the work in places where the pattern is gated, or where numbers or letters may appear.

Second: In setting up a rough casting there should never be more than three fixed supporting points; any others which may be necessary for the proper support of the work must be made adjustable, with some approved method of clamping securely after adjustment.

Third: The work must be firmly secured so that no distortion can take place under the strain of clamping.

Fourth: When the work is of such a nature that difficulty is experienced in obtaining proper clamping surfaces, it is sometimes advisable

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to consult with the patternmaker in regard to the addition of clamping lugs to the pattern. In cases of this sort, these lugs should be so applied that their subsequent removal can be effected readily.

Fifth: In designing a chucking fixture the safety of the operator should be considered carefully, and by that is meant that protruding heads of screws, bolts, clamps and similar parts should be avoided as much as possible. A little forethought in this regard may be the means of saving an operator from mutilation or death.

Sixth: Convenience and accessibility in setting, locating and clamping the work, are also of primary importance.

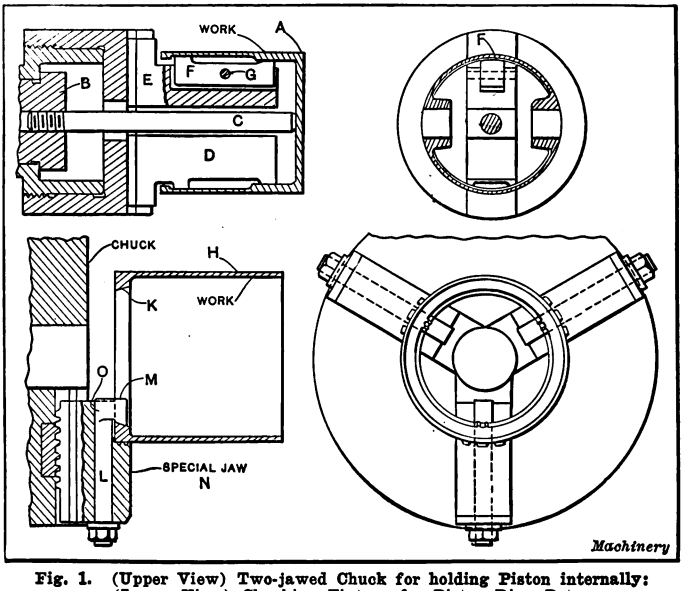


Fig. 1. (Upper View) Two-jawed Chuck for holding Piston internally: (Lower View) Chucking Fixture for Piston Ring Pot

Individual points regarding the work-holding devices shown in the illustrations will be discussed. We shall consider holding devices for the horizontal turret or chucking lathe, the vertical turret lathe, and the vertical boring mill. In describing these devices, the work and its requirements will be considered, as well as the important locating surfaces, the method of handling the work and important points in the design of different fixtures.

Two-jaw Chuck arranged for Internal Chucking

It is essential that the cast-iron piston shown in the upper part of Fig. 1 be located from the cored interior, in order to have the outer walls concentric with the core, thus obtaining an equal distribution of metal throughout the piston walls. Due to the formation of this casting, the core is poorly supported at the closed end and, therefore, has a tendency to drop slightly when the metal is poured into the

mold, thereby producing a lack of concentricity between the cored portion and the exterior surfaces. It is logical then, in order to obtain uniform results, to work from the cored portion when setting up the casting. Many methods of holding have been devised for this purpose. The fixture shown in Fig. 1 is one of the simplest, an ordinary two-jaw chuck with special internal jaws being used for holding and locating the work *A*. A steel bushing *B*, fastened into the spindle, contains the stop-rod *C*, which comes against the head of the piston, thus insuring a uniform thickness of metal at this point. The chuck is supplied with the two special jaws *D* and *E*. The former is a plain jaw with two bearing points, while the other has a swivel-jaw *F*, pivoted on the pin *G*, which allows it to conform to the inequalities of the casting. This method of chucking is one of the cheapest, and the results obtained by its use are fairly satisfactory. There is a tendency toward inequality in the thickness of the piston walls in the direction of the wrist-pin bosses, due to the fact that the centering action of a chuck of this type is in two directions only; however, at least one large manufacturer in the East uses this method entirely. The chuck is employed for rough-turning only, thus securing a partially finished surface which is true with the core and which may be used to work from for subsequent operations.

The work *H*, shown in the lower view of Fig. 1, is a cast-iron piston ring pot, which must be held in such a way that it can be bored, turned eccentrically, and separated into narrow rings for a gas engine piston. As the ring pot is very thin, it must be carefully held to avoid distortion and yet be very rigidly secured, as there are several tools working at one time so that the torsion produced by the cut is excessive. The pot is made with an internal gripping ring *K*, which is slightly beveled to assist in keeping it back against the chuck jaws. The chuck is an ordinary three-jaw, geared-scroll type, having jaws as shown in section at *N*. These jaws are of steel and are drilled to receive the hook-bolts *L* which pass entirely through them and grip the ring from the inside. The heads of the bolts *M* come out through slots in the jaws, the heel having a backing at *O*. When setting a casting the bolts are left free while the jaws are brought up against the outside of the casting with just enough pressure to get a bearing. The bolts are then set up tightly on the gripping ring, so that the work is held firmly but without distortion. This method is very good and can be applied successfully to many varieties of thin work. The hook-bolts are of tool steel and are hardened and drawn to a deep straw on the hook end. The backing up of the hook-bolt at *O* is very important, for unless properly supported at this point its action is greatly impaired and it soon becomes bent out of shape and is absolutely useless.

Ring Pot locating Fixture without Chuck-jaws

Another cast-iron ring pot of somewhat different form is shown in Fig. 2. The operations on this piece are identical with those for the

casting shown in the previous illustration, but the holding method is entirely different. This form of pot is used by one of the largest manufacturers in this country. Before it is placed in the fixture, the face of the gripping ring *A* is ground square with the outside of the pot. The body of the fixture *B* is of cast iron and is screwed fast to the spindle nose of the horizontal turret lathe upon which it is used. The annular ring or pad against which the ring pot lies is faced square in position on the machine. A hardened and ground tool-steel bushing *C* is accurately fitted to the inside of the spindle and is held in position by the teat-screw *D*. It will be noted that this bushing also acts as a guide for the boring-bar pilot *E*. A tapered plunger *F* is forced outward by the spring *G* and centralizes the inside of the

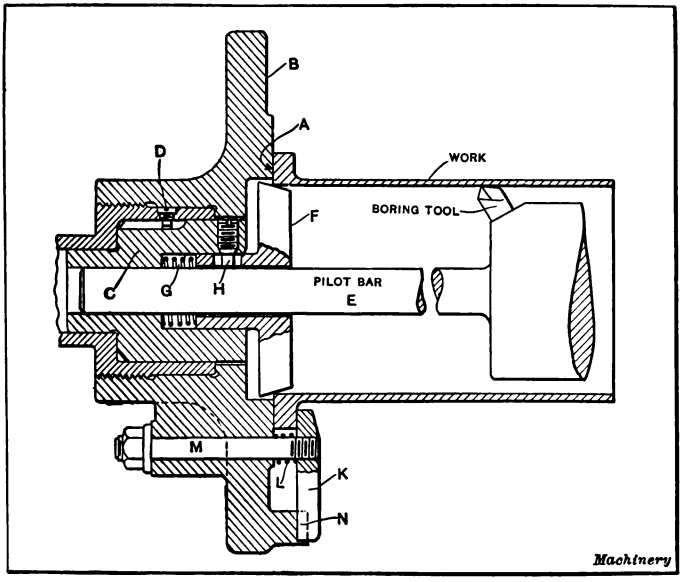


Fig. 2. Another Ring Pot Chucking Fixture

pot. The screw *H* simply acts as a retainer to keep the plunger in position. There are three clamps, 120 degrees apart, on the face of the fixture. One of these is shown at *K;* obviously this is tightened by the screw *M*, while the coil spring *L* serves to keep the clamp away from the work when not in use. The lug *N* prevents the clamp from twisting around when the screw is being tightened. This fixture is a very good one, except that its operation is rather slow.

Locating Fixture for a Ball-and-socket Pipe Joint

The requirements for the work shown in Fig. 3 need little explanation. The piece itself is a steel casting. A cast-iron "cat-head" or fixture *A* is screwed onto the spindle nose, and is faced at *B* to an arc corresponding with the rough ball-portion of the pipe joint. The two

hook-bolts *C* obviously grip the work from the inside and hold it firmly against the finished face *B*. A centering plug *E* fits the turret hole and is brought up and entered into the casting before the hook-bolts are set up tightly. This fixture was not entirely satisfactory owing to the condition of the rough castings at the end *F*, for at this point they varied greatly and were very rough, making the holding somewhat uncertain. A method of holding this work by the interior undoubtedly would have been more satisfactory.

Chucking Device having an Outboard Supplementary Bearing

The automobile tail-shaft housing shown at *B* in Fig. 4 is made of malleable iron and is so long that chucking by means of jaws is out of the question, on account of the excessive overhang which would be

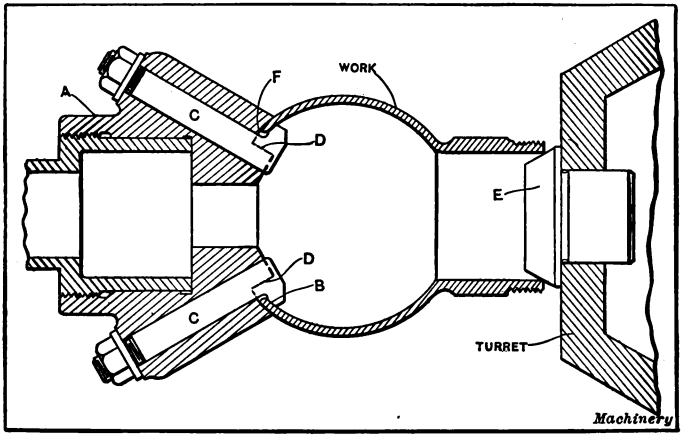


Fig. 3. Fixture for Ball-and-socket Pipe Joint

necessary. The piece was to be finished complete in one setting and the fixture shown was designed and used for this purpose. The body *C* is of cast iron and is screwed onto the spindle nose. The inner cylindrical surface *D* is very carefully bored and the outer bearing surface *E* is turned and finally lapped to a nice running fit in the bracket *A*. The periphery *H* of the locating and centering bushing *F* is crowned on a radius and is slotted in various places, as shown at *K*, to receive the exterior ribs on the housing. A pointed set-screw *G* keeps the bushing in position. The tapered plug *L* is located in the turret hole and serves to center the work, and the pointed set-screws *M* (three of which are used) are sunk into the casting and act as drivers in addition to holding it in the position determined by the tapered plug. The bracket *A* (also shown in detail) acts as an outboard bearing for the long body of the fixture and prevents the vibration which would otherwise result from the excessive overhang. A glass oil cup was an added refinement to the equipment and may be noted at *N*.

Method of Chucking One-half of a Rear-axle Housing

The male portion of an automobile rear axle housing is shown in Fig. 5. This is machined in one setting on a horizontal turret lathe. The body of the fixture *B* is of cast iron and is screwed onto the nose of the spindle. Three steel pins *C* are located 120 degrees apart, around the inside of the fixture body, the coil springs *D* forcing them outward and the set-screws *E* securing them in place when properly located against the work. The method of clamping is somewhat peculiar and should be carefully noted. The swinging dogs *F* have a knife-edge at *K* and are pivoted on the pins *G*, which are set back in such a position that the action of the dogs (controlled by the hollow set-screws *H*) has a tendency to carry the work back against the body of the fixture and the spring jack pins. A steel bushing *L* is forced onto the small end of the work and assists in centering it in the spindle. This bushing is crowned on a radius the same as that shown in Fig. 4. The taper locating plunger *N* is forced out by the spring *O* and is restricted in its action by the pin *P*. The two-arm support *Q* is of cast iron and is of assistance in keeping the work in position while the various screws and dogs are being tightened. The bushing *M* acts as a guide for the boring-bars and reamers used in machining the work. The work is driven by the ribs *R*, which enter slots in the body of the fixture. This method of holding gave satisfactory results, although considerable care was necessary to avoid springing the casting when tightening the clamping dogs.

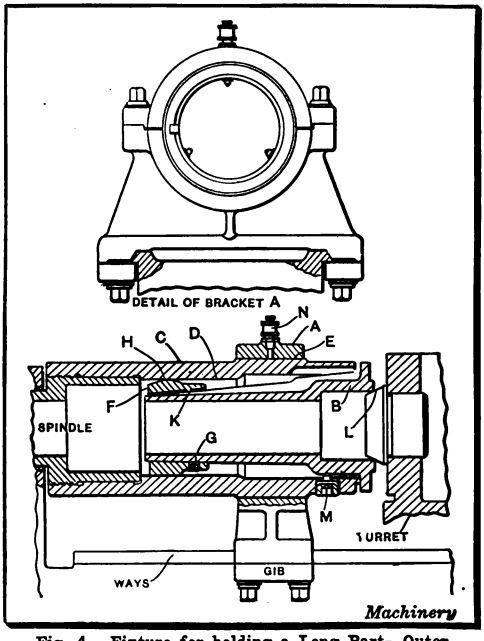


Fig. 4. Fixture for holding a Long Part—Outer End is supported by Bracket

Equalizing Pin Chuck for a Gas Engine Piston

One of the many varieties of internal holding piston chucks is illustrated in Fig. 6. Although rather expensive, it is an excellent example of this type of chuck, and is very well made. All working parts are of steel or bronze and all parts requiring such treatment are carefully hardened and ground. The body of the chuck is of ma-

chine steel, carbonized, pack-hardened and ground; the pins, cams, operating rod, screws and bushings are of tool steel; while the miter gears are of bronze. The body of the chuck *A* is screwed onto the spindle nose and is ground or lapped at all important points. The operating cams *B* and *C* are slotted in three places around the periphery at *D* and *E*, these slots being angular and forcing the six pins *F* and *G* out against the interior walls of the piston. It may be noted that the steel plates *H* and *K* are let into the body of the chuck, and act as retainers for the pins. These plates are clearly shown in the upper view. The operating rod *L* is revolved through the action of the miter gears *M* and *N*. The latter has a key *T* engaging a long spline in the operating rod, which is thereby permitted to move longitudinally. The threaded portion *U* is 6-pitch right-hand thread, while that at *V* is 6-pitch left-hand thread. The forward cam is packed with felt at *X* to keep out the dirt. The bushing *O* is of tool steel, hardened and ground. The plug *Q* simply closes the hole which has been put in for assembling purposes.

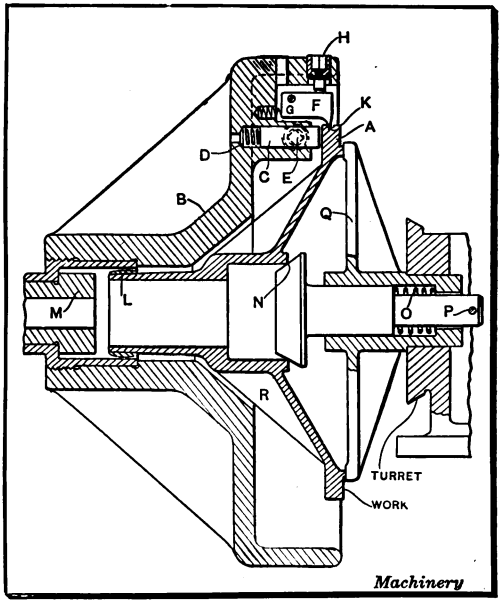


Fig. 5. Casting A held so that it can be machined at One Setting

By referring to the upper view it will be seen that the chuck body is cut away on the sides at *R* and *S*, on account of the wrist-pin bosses in the piston, and the overhanging lip at *R* acts as a driver. In designing a chuck of this kind, it must be remembered that while the rear clamping pins may be equally spaced, the position of the forward pins will be determined by the diameter and spacing of the wrist-pin bosses, and an end view will be found essential to determine the correct position. In general it will be found that two of the forward pins seldom can be spaced more than 80 degrees apart and often the spacing cannot be made more than 55 or 60 degrees. Another point in design which is of great importance is the amount of clearance between the ends of the wrist-pin bosses and the flattened sides of the chuck body. It is seldom safe to allow a clearance of less than 3/16 inch on each side, over the finished sizes called for on the drawing

of the piston. The location of the stop-pins *W* is also important, and sufficient allowance should be made in the length of the cam slots to take care of variations in the piston castings. A chuck of this type gives results which are satisfactory in every respect.

An Equalizing Pin Chuck for an Electric Generator Frame

The examples which have been referred to in the foregoing are all adapted for use on the horizontal type of turret lathe, but we shall now go a step farther and take up chucking devices designed for the vertical turret lathe and the vertical boring mill. As machines of this type are adapted more to heavier classes of work, the fixtures

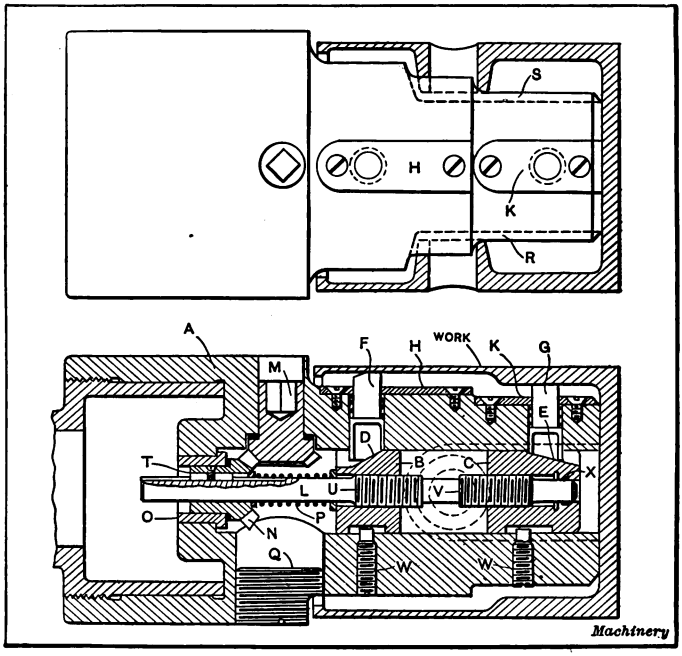


Fig. 6. Special Chuck for holding Gas Engine Pistons internally

should be designed with relation to the work and also to the power of the machines upon which they are to be used. For machining the steel generator frame shown on the fixture in Fig. 7, the working points specified by the manufacturer are at *B* between the ribs *C* on the upper portion of the casting *A*. It was further specified that the work must be held by the core to insure an evenly balanced casting.

The design of this chuck resembles that shown in Fig. 6, in that both chucks are fitted with pins and operating cams; the operating mechanism, however, is entirely different. The body of the chuck *D* is of cast iron; it is carefully reamed and lapped at important points, and is securely fastened down to the table of the machine by three screws having tee-shaped heads, which enter the table T-slots

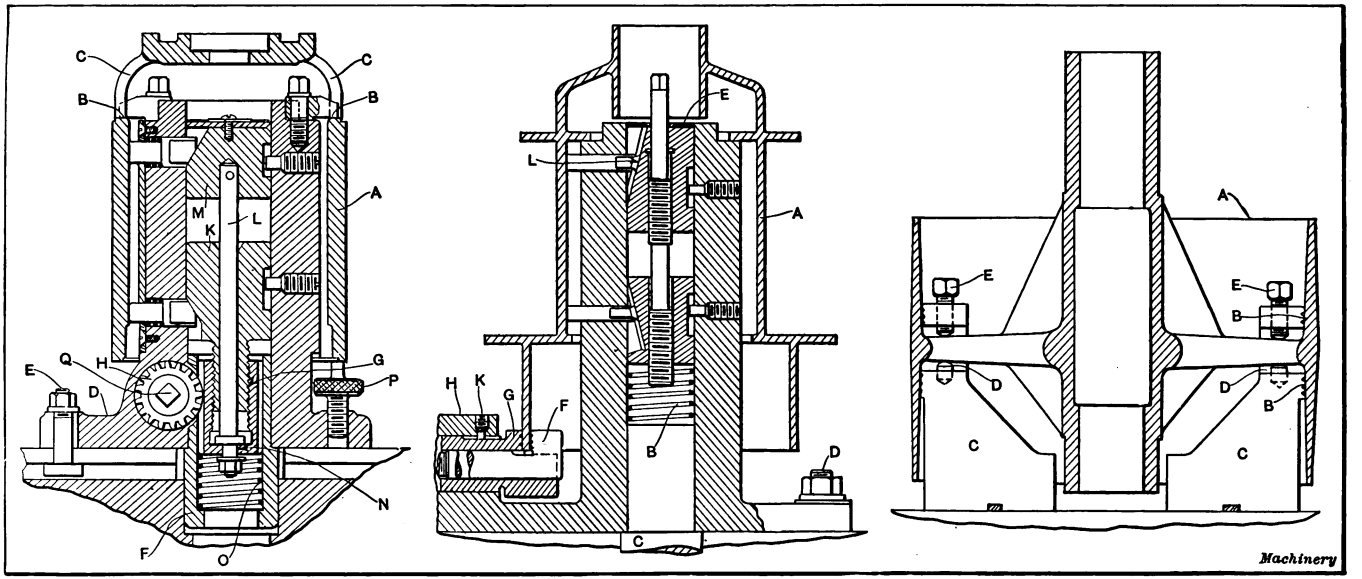


Fig. 7. Vertical Boring Mill Fixture for holding Part A internally

Fig. 8. Vertical Fixture having Internal Clamping Pins and Hook-bolt Clamps for Lower Flange

Fig. 9. Special Chucking Jaws for Large Pulley

as shown at *E*. The fixture is centered by the hollow stud *F*, which is of tool steel, hardened and ground inside and out. This stud also acts as a bushing for the operating sleeve *G* and is cut away for clearance on one side where the spiral gear *H* passes through it. This gear meshes with another which is cut on the outside of the operating sleeve. The latter is of bronze and it is threaded internally with a 6-pitch Acme thread, corresponding with that cut upon the lower end of the cam *K*. The operating rod *L* is pinned into the upper cam *M* and is shouldered and journaled at its

lower end where it passes through the operating sleeve at *N*. The coil spring *O* is so proportioned that it simply supports the cam mechanism and assists in releasing. It will be noted that the arrangement of this internal mechanism permits a "floating" action for the cams, so that the clamping pins all bear uniformly against the inner walls of the casting. In setting up the work on the fixture, it is dropped over the top until the lower end rests on the three adjusting jacks *P*, which are placed 120 degrees apart and are knurled for finger adjustment. The upper locating arms *B* are swung back out of the way while the casting is being set in position, but as soon as this has been done they are brought around into the position required. The jacks are next raised until the casting has been properly located against the arms; then a long-handled socket wrench is inserted at *Q* and the gearing is revolved until the pins are securely seated against the inner walls of the work.

A Combination Device having Equalizing Pins and Hook-bolts

The piece shown at *A* in Fig. 8 is a clutch pulley for a gasoline tractor. It is made of cast iron and the method of holding from the inside was decided upon because it seemed to offer better facilities for machining. As in a former example, the body of the fixture contains the cams and the operating rod which is threaded right- and left-hand, as before. The lower ends of the pins and the slots in the cams are dovetailed in this instance, so that the outward and inward movements are controlled mechanically, no springs or plates being required. The fixture is centrally located on the machine table by the plug *C*, which fits the center hole in the table and is held down in the usual manner by the T-bolts shown at *D*. The coil spring *B* simply acts as a support for the cams and rod. An annular groove is cut in the upper cam at *E* and this is packed with felt to assist in keeping the dirt out of the working parts. The lower part of the fixture has three bosses (one of which is partially shown at *H*), which contain the floating jaws and hook-bolts, *G* and *F*, for clamping the lower flange of the pulley. The construction of these parts is more clearly shown in Fig. 10, and, as they are identical the reader is referred to the portions marked *C* and *D* in that illustration. The results obtained by the use of this fixture were at first very satisfactory, but, after a time, the dirt which gradually accumulated in the dovetail cam slots, began to cause trouble, until, finally, it became almost impossible to operate the mechanism. Then, too, in several cases the dovetail part broke off completely, necessitating new pins, so that the chuck as a whole cannot be considered an absolute success. No trouble would have been experienced if the cam slots and pins had been made as shown in Fig. 7, with coil springs and retaining plates.

A Set of Special Jaws for a Large Crowned Pulley

The large farm engine pulley shown at *A* in Fig. 9 is of cast iron, and it must be held by the inside in such a way that it will not be

distorted while fairly heavy cutting is being done on the periphery of the pulley. A four-jaw table was selected on which to hold the work, as there were eight spokes in the pulley. The chuck jaws *C* were made of 0.40 per cent carbon steel and were slotted out for the spokes as shown in the illustration. The hardened steel studs *D* were set into the slots, and the set-screws *E* brought down tightly on them after the jaw surfaces *B* had been brought out to center the pulley.

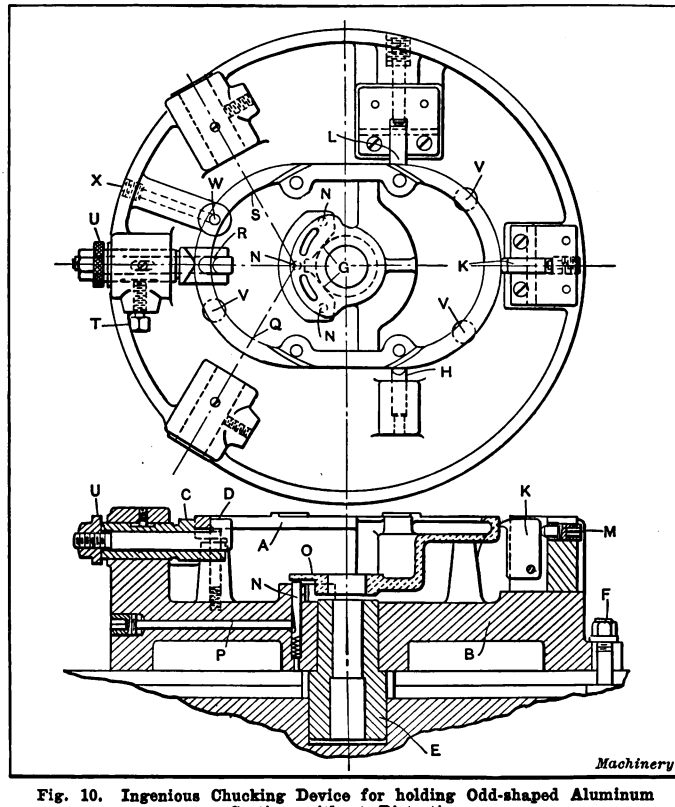


Fig. 10. Ingenious Chucking Device for holding Odd-shaped Aluminum Casting without Distortion

This method of holding pulleys or other spoked work gives very satisfactory results and is used by many manufacturers throughout the country.

A Chucking Device for a Difficult Piece of Electrical Work

The aluminum piece shown in Fig. 10 is one of the most difficult for which there ever is an occasion to make a chucking fixture. The walls of the entire piece were of very thin section, and the overhanging portion *A* was elliptical in shape and entirely unsupported. It was necessary to so hold this casting that it could be machined without

distortion. The body of the fixture *B* is of cast iron. It is centrally located on the table by means of the hollow bushing *E*, and clamped down by T-bolts shown at *F* in the table T-slots. A portion of the fixture shown in the upper view at *G* was cut out to form a V, in which the cylindrical portion of the casting is centered. One of the sides of the casting is located against the knife-edged pin *H* (shown in the upper view), and the casting is forced into the V and against this knife-edged surface by the swinging clamps *K* and *L*. It will be noted that these clamps also have a knife-edge and that the pins upon which they are hung are in such a position that their action is downward, thereby tending to hold the work securely against its supports. Hollow set-screws *M* control the action of these swinging clamps. There are three spring-pins *N* which are used to support the very thin flange *O*, and the springs which force them upward are carefully proportioned so that they have just sufficient strength to insure contact without springing the work. These pins are locked in their positions by the long hollow set-screws *P*, shown in the lower view.

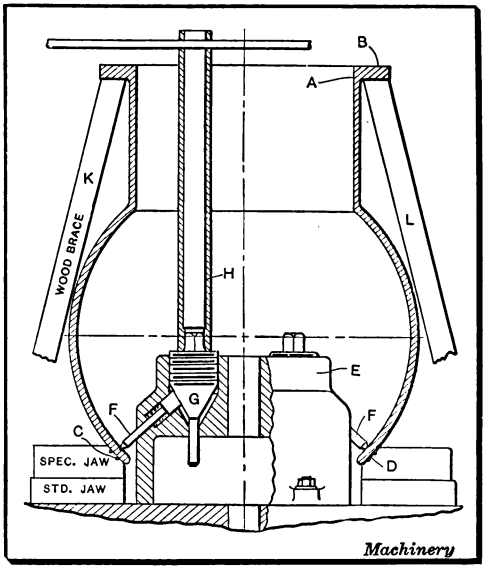


Fig. 11. Vertical Boring Mill Fixture for holding Large Ball Joint

One of the principal points of interest in this fixture is the method of gripping the overhanging elliptical portion *A*, without distorting the casting. This is accomplished by means of the floating jaw *C* and the hook-bolt *D*. There are three of these floating clamps which grip the work at points *Q*, *R*, and *S* (see plan view). It will be noted that the clamps are free to "float" laterally, until the set-screws at *T* are tightened. The knurled hexagon nut *U* is threaded onto the head of the hook-bolt, and is lightly tightened by means of the fingers before the final tightening with a wrench. As these clamps have a perfectly free floating action, until the binding screws are tightened, obviously there can be no distortion of the piece, and yet it is held rigidly at these points. When the work is placed into the fixture it rests upon three fixed points shown in the plan view at *V* and a fourth point *W*. The latter is held upward by a light spring and it is locked in position by the long hollow set-screw *X*.

The work accomplished by the use of this fixture was true and accurate, no evidence of springing out of true being apparent.

Boring Mill Fixtures for a Large Ball Joint

The work shown at *A* in Fig. 11 is a large ball pipe joint for a suction dredge, and it is to be faced on the upper surface *B*. Two designs were made for this work, neither of which was used, but as the conditions are somewhat peculiar the fixtures will be described, and may be taken for what they are worth. The special jaws *C* and *D* are bored to an arc corresponding with the ball, and the work rests upon and is centered by these jaws. The body of the clamping device *E* is of cast iron and is bolted down to the table. It contains four pointed screws *F*, which, normally, are kept away from the work by means of coil springs. The ends of the screws are beveled to the same taper as the operating screws *G*, which are threaded at their upper ends with a coarse pitch thread, and have squares to receive the end of the long socket-wrench *H*, by means of which the screw is revolved, thus causing the points to sink down into the casting. Wood braces are used to support the flange which is to be faced. Four are used, although only two (*K* and *L*) are shown in the illustration. This fixture would have been rather expensive, but doubtless would have produced satisfactory results.

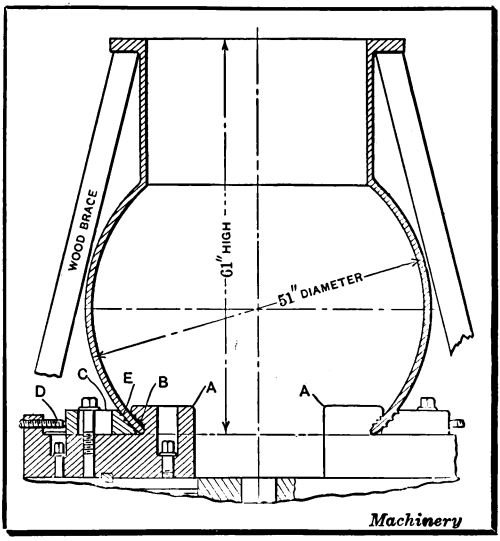


Fig. 12. Another Method of holding Large Ball Joint

Fig. 12 illustrates another fixture for holding the same piece of work, which probably would have given more satisfactory results than the one shown in the previous illustration. It could have been manipulated more rapidly, because it is more accessible to the operator. Four sets of special jaws *A* are used for holding the work. The part *B* is formed to an arc corresponding to that part of the work which it grips, and has teeth to assist in obtaining a firm "bite." The supplementary sliding jaw *C* is forced into position by the set-screw *D*, thus clamping the work tightly between *B* and *E*. Wooden supports are used under the flange.

CHAPTER II

ARBORS FOR SECOND-OPERATION WORK

Cylindrical work which cannot be completely machined in one setting and which requires concentricity of the various surfaces obviously makes necessary some method of holding it for the second operation which utilizes a previously machined surface for securing the proper location. When this surface is external, the use of soft jaws, a step-chuck or collet jaws is feasible, but when an internal surface is the locating point the most efficient method is conceded to be some form of arbor. This arbor may be either a plain stud made to fit the hole

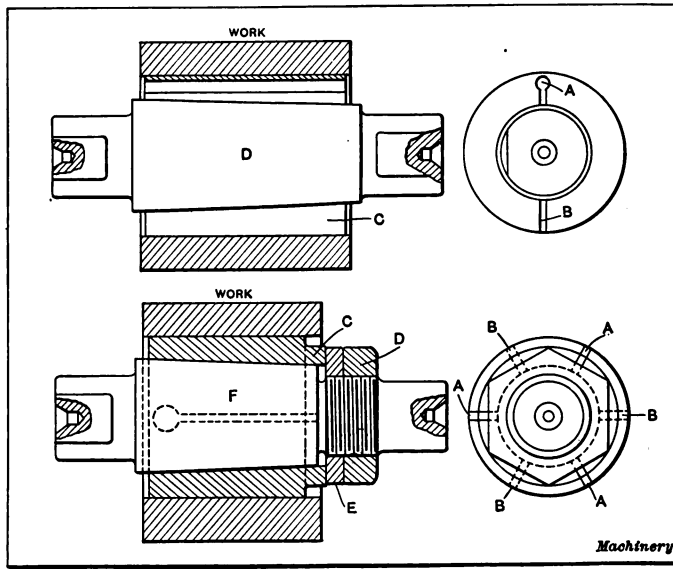


Fig. 1. Two Types of Expansion Arbors with Split Sleeves

in question, or it may be so designed as to be susceptible of a certain amount of expansion and contraction in order to take care of slight variations in the finished hole. The degree of accuracy required in the finished product determines the form of arbor which should be used. If a variation of 0.002 to 0.003 inch in concentricity is permissible, a plain arbor with some method of driving the work will answer the purpose very well. When very accurate work is required, however, greater care must be used in the design, and the expanding type of arbor is commonly used.

Important Points in Design of Arbors

The fundamental features which tend to make an arbor thoroughly efficient are as follows: Expansion must be uniform along the entire periphery; release must be quick and easy; ample driving facilities must be provided; clamping the work must be effected without chance of distortion. As an additional refinement, provision may be made for truing up the arbor so that it will run accurately with the center line of the spindle.

Lathe Arbors

Let us first consider the arbors designed for use in the engine lathe, adapted to be held between centers and driven by means of a dog on one end. The arbor shown in the upper part of Fig. 1 is the simplest of all those which have a split sleeve or bushing capable of expansion

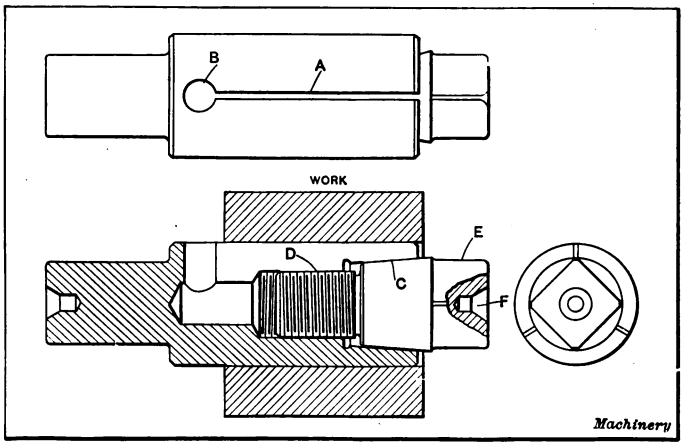


Fig. 2. Arbor expanded by Internal Taper Plug

or contraction. The mandrel *D* is slightly tapered and is flattened on each end to receive the dog for driving. The sleeve *C* is correspondingly tapered and is drilled entirely through at *A*, after which it is saw-cut at *B* is allow for expansion. This arbor is the poorest of all the expanding types in that the expansion is not uniform, being in two directions only, and it cannot be depended upon to give results which are absolutely accurate.

A much better arbor is shown in the lower part of the same illustration. It will be noted that the mandrel *F*, in addition to being tapered, is threaded on one end to receive the hexagon nut *D*. This does away with the necessity of using the arbor press to expand the sleeve. The collar *E* is interposed between the nut and the split bushing. This bushing *C* is saw-cut at *A* from one end and at *B* from the other, thus allowing a uniform expansion along its entire periphery. In this connection, it is well to note that the ends of the saw-cuts should be left tied together until after the sleeve has been hardened and ground; they can then be cut apart readily with a thin emery

wheel. An arbor of this kind is mechanically correct and, if carefully made, should give results which leave nothing to be desired as far as accuracy is concerned.

Fig. 2 shows an arbor of a very different type, which might be called a solid expanding arbor. Three holes *B* are drilled 120 degrees apart and the saw-cuts *A* are milled as shown. The special screw *E* is tapered at *C* and threaded at *D* in the body of the arbor. The end of this screw is squared and contains the center *F*. When made as shown there is nothing in this arbor to commend it. In the first place, the expansion takes place at one end only and is not at all uniform, and, in the second place, the center *F* in the end of the screw cannot be depended upon to remain true for any length of time, even assuming that it may have been made reasonably true to start with, which, in itself, is a difficult machining proposition.

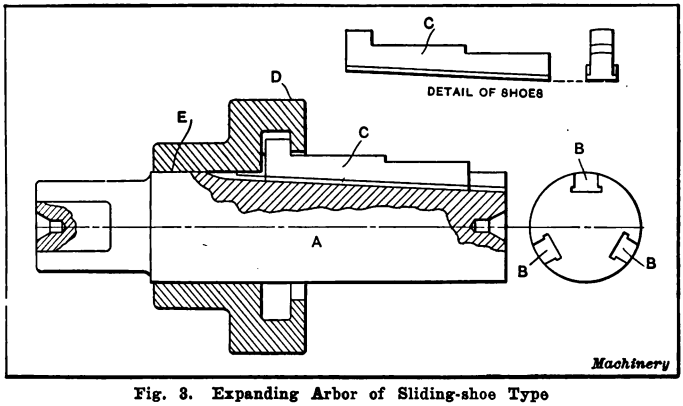


Fig. 3. Expanding Arbor of Sliding-shoe Type

The arbor shown in Fig. 3 was at one time manufactured commercially by G. E. Le Count, South Norwalk, Conn., but the writer is unable to state whether it is on the market at the present time or not. It consists of the body *A* in which are milled the tapered slots *B*. The shoes *C* (also shown in detail in the upper part of the illustration) have a narrow rib running along each side and this rib engages with the grooves in the sides of the slots *B*, thus preventing the shoes from falling out. The collar *D* controls the action of the shoes and is ground to a sliding fit on the cylindrical portion *E* of the arbor. It may be noted that the shoes have two shoulders, thus increasing the range of the arbor. By providing shoes of various diameters the range can be increased considerably.

W. H. Nicholson & Co., Wilkesbarre, Pa., manufacture the expanding arbor shown in Fig. 9 in various sizes and to suit various conditions.. The body *A* is made of tool steel, hardened and ground to a cylindrical form. The centers are exceptionally large and are carefully rounded and lead-lapped after hardening. There are four slots in the body (shown in the section *A-B*), and these slots are relieved at

each corner to prevent any interference by dirt. After hardening, the slots are also ground to insure truth. The jaws *C* (also shown in detail) are made of special steel and carefully ground to the same taper as the slots. After assembling, they are also ground radially on their own arbor. The sleeve *D* acts as a retainer for the jaws and is a running fit on the cylindrical portion *E* of the arbor. Four slots are cut through the sleeve and the jaws are held in position by them. These arbors are too well known to need further comment, as they are in general use throughout the country.

Turret Lathe Arbors

We will now go a step further and take up the type of arbors adapted for use in the horizontal turret lathe. It is well to bear in

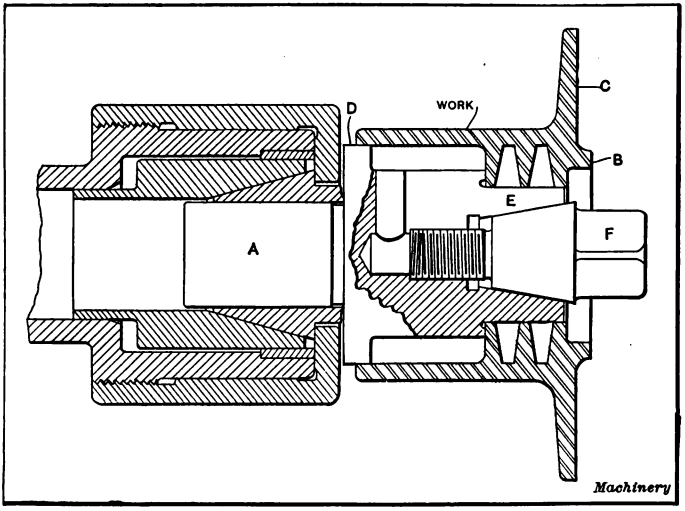


Fig. 4. Arbor held in Collet and expanded by Internal Taper Plug

mind that arbors of this sort should be so designed that the work may be easily and quickly put on and taken off without the assistance of anything more than a wrench or spanner. Every precaution must also be used in clamping and driving the work, so that no chance for distortion is possible.

The arbor shown in Fig. 4 is somewhat similar in construction to that in Fig. 2, except that it is adapted to be held in collet jaws instead of on centers, as in the former instance. This arbor gave satisfactory results on the work for which it was used, the surfaces *B* and *C* being faced within the required limits of accuracy. The work was a push fit on the cylindrical portion *D*, the expansion taking place at *E*, controlled by the tapered screw *F*. In this case, the nature of the work permitted a slight margin of error and the expansion was only necessary to prevent chatter and act as a driver. The shank *A* is held in the collet jaws.

The arbor shown in Fig. 5 was made for the transmission gear which is shown in position. After the taper hole had been "chucked" in the work (which was done in a previous setting) the keyway *A* was cut for assistance in driving. The arbor body *B* is of cast iron, ground to fit the spindle at *C* and *D*. The stem *G* is of steel, hardened and ground to fit the body, into which it is keyed to resist the torsion of the cut. It is held in position and drawn back by the nut and collar *L* and *M*. The forward end is ground to the correct taper *E*, and the key is inserted at *A*. The portion *F* is threaded with a six-pitch Acme thread, right-hand, and the nut *H* is used to remove the piece after the work is finished, a piece of drill rod being used in the spanner hole *K* to turn the nut. The screw *N* prevents the body from turning in the spindle. This arbor has given very satisfactory results.

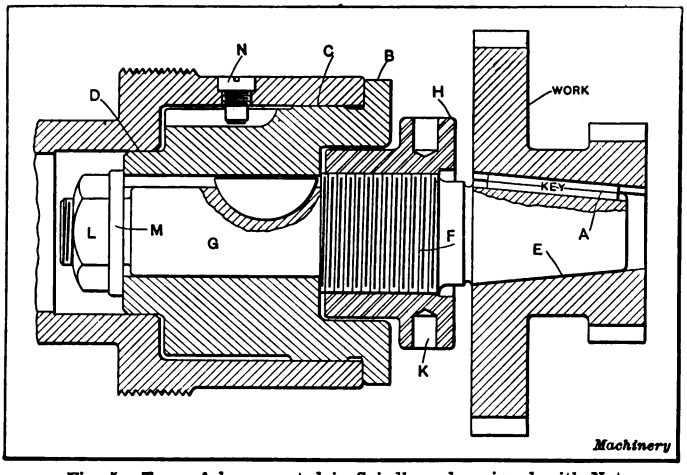


Fig. 5. Taper Arbor mounted in Spindle and equipped with Nut for removing Work

A somewhat extraordinary condition is shown in Fig. 6, which illustrates a steel automobile hub and arbor. In this case, the bearing seats at *A* and *B* were required to be absolutely concentric. In order to assist in machining, the portion *C* was bored to size in the first setting, although no finish was required at this point. The body of the arbor *D* is of tool steel, hardened and ground at all important points. The small end is slotted at three places as shown at *F* and is spring tempered at this end. The operating rod *K* has a very free thread at *H* and is ground to a snug running fit in the cylindrical portion *G* to insure true running, regardless of the condition of the threaded part. All the tools used on surface *B* of the work were piloted by the stem or extension of rod *K*, thus securing absolute truth and concentricity of the ends *A* and *B*.

There are several important points to be noted in the construction of this arbor. First, the method of obtaining a true running stem or

extension of rod *K* by means of the long cylindrical bearing at *G;* second, the use of the stem as a pilot for tools, thereby obtaining concentricity in the two ends of the work *A* and *B;* third, the positive location of one end at *A*, while using an expansion principle at the other end to insure rigidity and freedom from chatter. This arbor was very satisfactory, the two ends being within the extremely narrow limits of concentricity required.

An entirely different type is illustrated in Fig. 7. This is used for two different sizes of bronze bearing retainers, the use of adapters making this feasible. In the construction of this arbor, the body *A* is screwed directly onto the spindle nose, bringing up snugly against

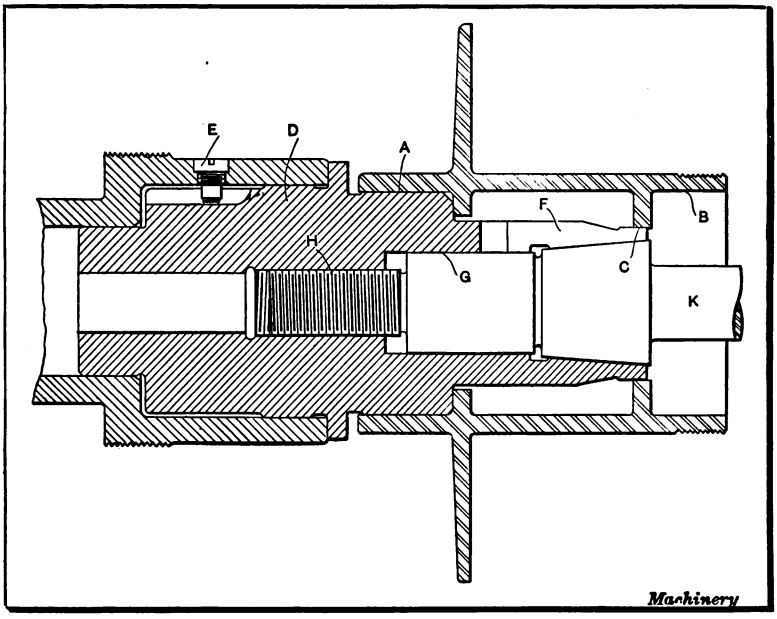


Fig. 6. Arbor with Split Expanding End and Pilot for steadying Tools

the end of the spindle at *B*. The body itself is of steel and is tapped out at *C* to receive the operating screw *E*. As in Fig. 6, the thread is a free fit, while the cylindrical portion *D* is ground to a snug running fit to insure concentricity. The bushing *F* is saw-cut in six places, three cuts from one end running nearly through, and the other three in like manner, in order to allow uniform expansion of the bushing. Both the bushing and the operating screw are tapered correspondingly at *G*. The adapter *H* slips onto the body of the arbor and is located from shoulder *M* and secured in place by three screws *N*. A pin driver *L* in the adapter relieves the bushing of excessive strain. The larger retainer *O* (shown in detail) is also handled on this same arbor by using the adapter *K*. The results obtained with this arbor were perfectly satisfactory.

In Fig. 8 the principles of expansion and contraction are both used in handling steel rifle part *A*. The permissible limits of error on this work were very close, so that extremely careful workmanship was necessary. This operation was the final one on the piece, after it had been machined all over, leaving 0.015 inch at *C* for truing to insure absolute concentricity between surfaces *B* and *C*.

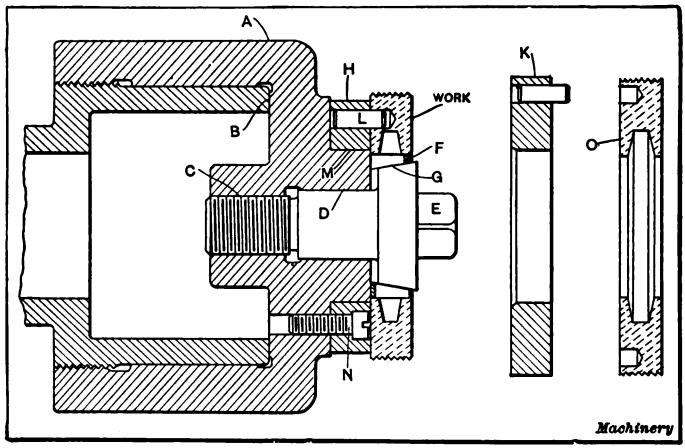


Fig. 7. Arbor having Taper Plug which expands Split Bushing

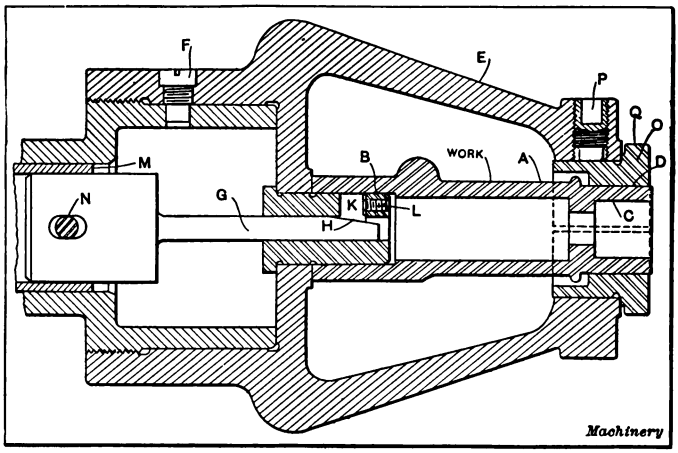


Fig. 8. A Fixture which holds Work by Expansion and Contraction

The machine to which this fixture was applied was equipped with collet mechanism, part of which was used in the operation. The body of the fixture *E* is of cast iron and is screwed onto the spindle nose, being secured against turning by the teat-screw *F*. The sides of the fixture were left open to enable the operator to reach in and grasp the work, in order to guide it onto the locating bushing *B*. The operat-

ing rod *G* was milled at an angle on the forward end *H*, in order to force the pin *K* outward and thus insure rigidity at this point. The collet operating sleeve *M* is secured to the rod by pin *N*, so that the collet closing mechanism can be used to operate the rod. At the forward end of the fixture, the split bushing *O* is used to center the work which is gripped on the finished cylindrical surface *D*. The bushing is knurled at *Q* and is contracted by the action of the hollow setscrew *P*. All important surfaces were ground to an accurate fit and parts subject to wear were hardened. No trouble was experienced with this fixture and the work was machined within the limits of accuracy required.

The steel pinion blank shown at *A* in Fig. 10 has been previously faced at *B* and the taper hole carefully bored, leaving the remainder of the work to be accomplished at the setting shown. The body *C*, in this instance, is of cast iron and is held in position by the teatscrew *D*. The arbor is of tool steel, carefully hardened and ground. The shoe *E* is shaped as shown in the detail above. The operating rod *F* is forced inward by screw *G*, and its release is effected by spring *H* which bears against its inner end. It should be noted that the action of shoe *E* is both outward and backward; therefore it has a tendency to force the work back onto the tapered portion. Obviously key *K* acts as a driver. In order to avoid any chance of springing the arbor out of true a small, special wrench is used for turning screw *G*, so that too much pressure cannot be applied. The nut *L* is threaded on the arbor with a coarse-pitch Acme thread and is of hexagon shape at the forward end. This nut is used to start the work off the arbor when the piece is finished. The stem or arbor *M* enters a bushing in the turret and acts as a support while the beveled surface of the work is being turned. This stem is also used as a pilot for the face mills which form the end of the pinion at *N*. This arbor while used for producing work of the best quality was somewhat fragile and required careful handling.

The pinion blank shown in Fig. 11 has a straight hole instead of a taper one, and the arbor for holding it, while somewhat similar in construction to that shown in Fig. 10, differs as regards a number of points. There are three shoes, *C*, 120 degrees apart, controlled, as to their outward movement, by the operating rod *F*. These shoes are retained in their positions by the thin circular spring *G*. The shoulder *H* on the arbor acts as a positive longitudinal stop for the work. The various sectional views give a good idea of the construction. This arbor is also of tool steel and all important surfaces are hardened and ground. It gave very satisfactory results, but the rather delicate construction necessitated careful handling.

Arbors for Vertical Boring Mill and Vertical Turret Lathe Work

We now come to a class of work of larger size, which can be more conveniently handled in the vertical boring mill or the vertical turret lathe. Arbors for comparatively large work frequently develop into

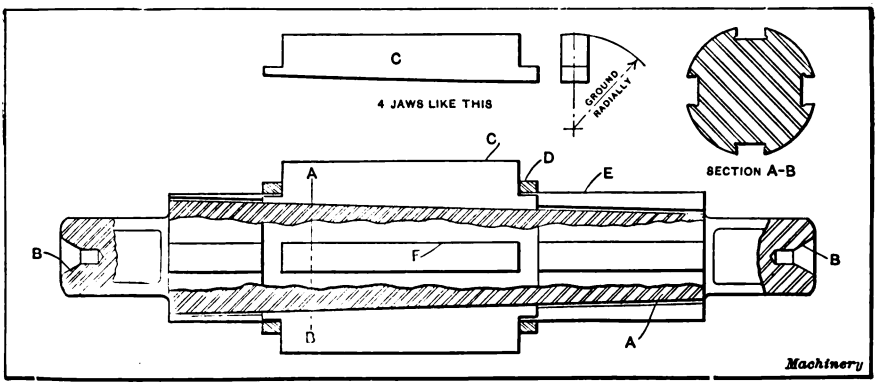


Fig. 9. Expanding Arbor with Sliding Shoes retained in Slotted Sleeve

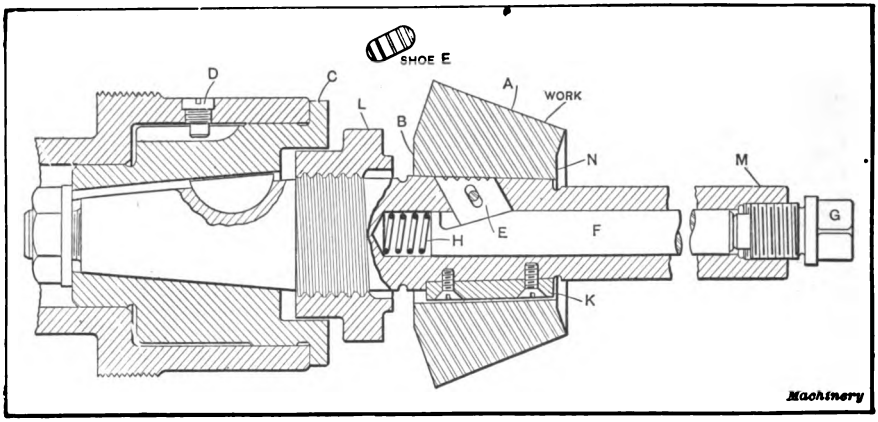


Fig. 10. Arbor having Adjustable Shoe E which bears against Taper Bore of Pinion Blank

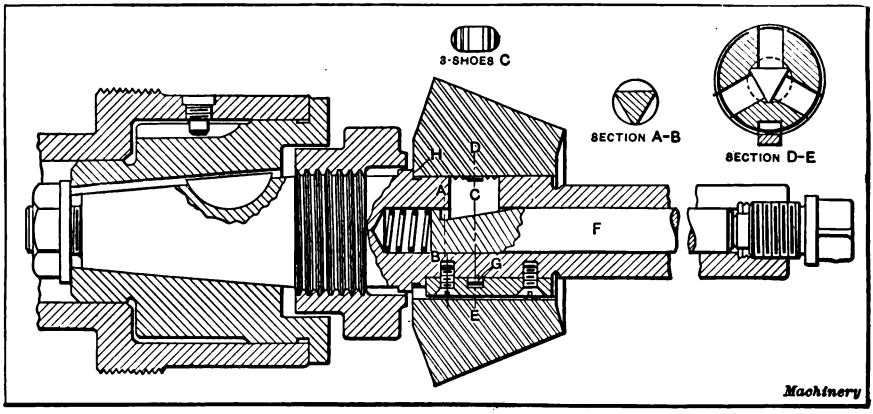


Fig. 11. Arbor for Pinion Blanks, equipped with Three Expanding Shoes

combination locating and holding devices, so that they are more nearly related to locating fixtures in the truest sense of the word. It is well to remember that in all fixtures of large size some efficient means of driving the work must be provided, for the thrust of the tool, incident to the cutting action, is much greater on work of large diameter; furthermore, the amount of stock to be removed is usually considerably more than on smaller work. The fixtures themselves

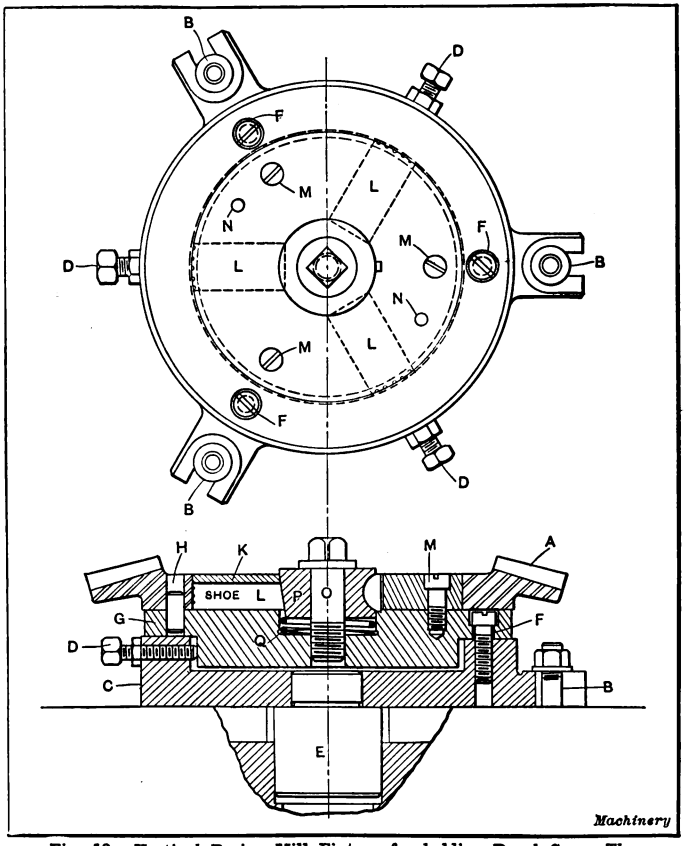


Fig. 12. Vertical Boring Mill Fixture for holding Bevel Gear—The Three Shoes L are forced outward by Plug in Center

should also be of exceptional strength and rigidly secured to the table to prevent movement or breakage.

The large automobile bevel driving gear shown in Fig. 12 is of alloy steel, and it has been previously bored and faced on the rear side; the screw holes were also drilled in a jig before placing the gear on the fixture shown. This fixture was rather expensive, being made entirely of steel (except the base, which is of cast iron), and all working parts were hardened and ground or lapped to a perfect fit. The base is

located in the center of the table by means of the locating stud *E*, and is securely fastened down by the three T-bolts *B* which enter T-slots in the table. The adjustable part *G* is held onto the base by the three screws *F*. It will be noted that the screw holes have a certain amount of clearance over the body of the screw to permit adjustments to be made. The screws and check-nuts at *D* are for the purpose of con-

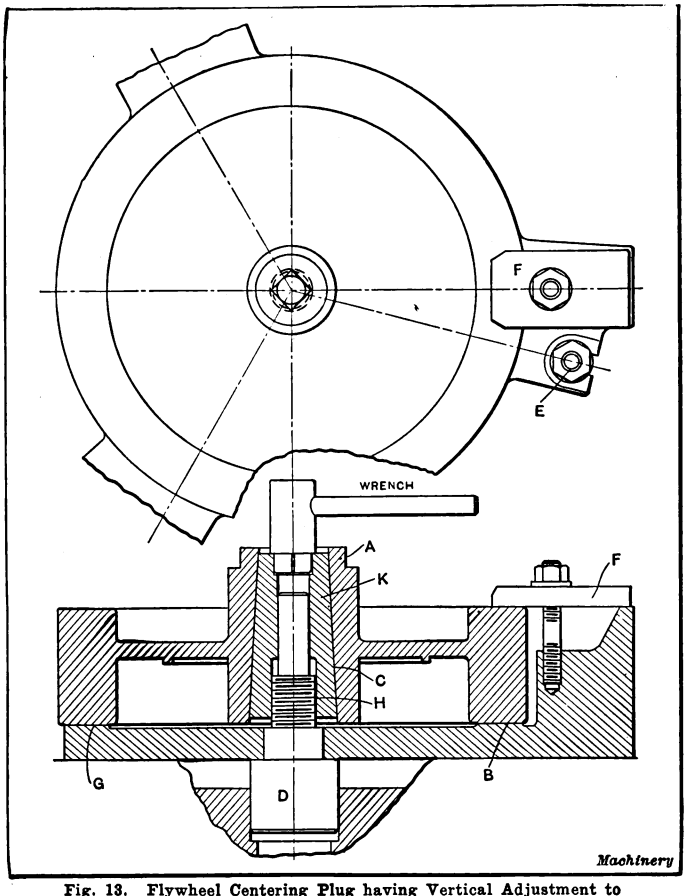


Fig. 13. Flywheel Centering Plug having Vertical Adjustment to compensate for Slight Variation between Bore and Rim Face

veniently adjusting the fixture. A pin-driver *H* engages one of the jig-drilled holes in the work. The upper plate *K* is square slotted at three points *L* to receive the shoes *L*. The screws *M* and the dowels *N* hold this plate in its proper position. The collar-head screw *O* forces down the plunger *P* on which three angular flat spots are milled. These angular surfaces control the action of the shoes *L* and force them out, uniformly, against the work, thus centering it. The spring *Q* simply aids in releasing the shoes.

This fixture is an exceptionally good one, for in its construction every care is taken to insure a true-running arbor and one which can readily be indicated for truth and brought into perfect concentricity by means of the adjusting screws. Its action was satisfactory in every respect.

Fig. 13 shows an automobile flywheel which has a finished taper hole and has been turned, bored and faced in a previous setting. It was essential that the surface *A* should be concentric with the taper hole. As it was practically impossible to machine the face of the flywheel *B* and the taper hole *C* so that they would always come in exactly the same relation to each other, it was necessary to make the taper plug adjustable in a vertical plane. The base of this fixture is of cast iron and is located centrally by means of plug *D* which accurately fits into the hole in the table. The base is clamped in position by three T-bolts *E* (see plan view) engaging the table T-slots. Three clamps *F* are used to clamp the work down on the annular rim *G* of the fixture. The plug *D* not only locates the fixture base, but extends above the latter and is threaded at *H*, while above this portion it is cylindrical and is carefully ground to a running fit in the taper bushing *K*. The threaded portion mentioned is a very free fit, so as to permit the cylindrical part to do all the centralizing. In using the fixture, the bushing *K* is screwed down and the flywheel placed in position, after which, by the aid of the wrench, the bushing is raised until it bears in the taper hole. After this, the clamps *F* are swung around and tightened. This is a simple fixture, rather inexpensive, and one which was thoroughly dependable.

Fig. 14 shows a cast-iron double-bevel gear used on harvesting machinery, the gear rings *A* and *B* having cast teeth. These were not machined, thus leaving a rough surface by which to clamp the work, as some support was needed in order to properly machine the annular ring *C*. The cylindrical hole *D* and the end *E* were machined at a previous setting.

The cast-iron base of the fixture is centered by the stud *F* which fits the center hole in the table. This stud extends up through the fixture and is tapered at its upper end to receive the split bushing *G*. This bushing is saw-cut in six places—three from each end—and is shouldered at its upper end so that the vertical movement can be controlled by the operating screw *H*. The collar *K* was pinned in place after the bushing was slipped over the screw. It will be noted that the vertical movement of the bushing is entirely mechanical, no springs being used to effect its release, as in previous instances. The positive locating point of the fixture is at *E*, but as it was necessary to have some support at *B* the four spring pins *L* were used; these bear against the rough surface of the casting and are prevented from being pushed down by the screws shown. The flat spot against which the screws bear is milled back at an angle of ten degrees. The rim of the gear has four cored holes and hook-bolts were necessary for holding and driving. These are shown at *M* in the illustration. In

this connection it is well to note that these hook-bolts are well backed up by a portion of the fixture *N*, for a hook-bolt which is not backed up in some way is worse than useless. This fixture was capable of rapid manipulation and the results obtained by its use were within the necessary limits of accuracy.

An Expanding Arbor for the Vertical Milling Machine

In one of the large automobile factories, considerable trouble was experienced in the manufacture of eccentric piston rings by the break-

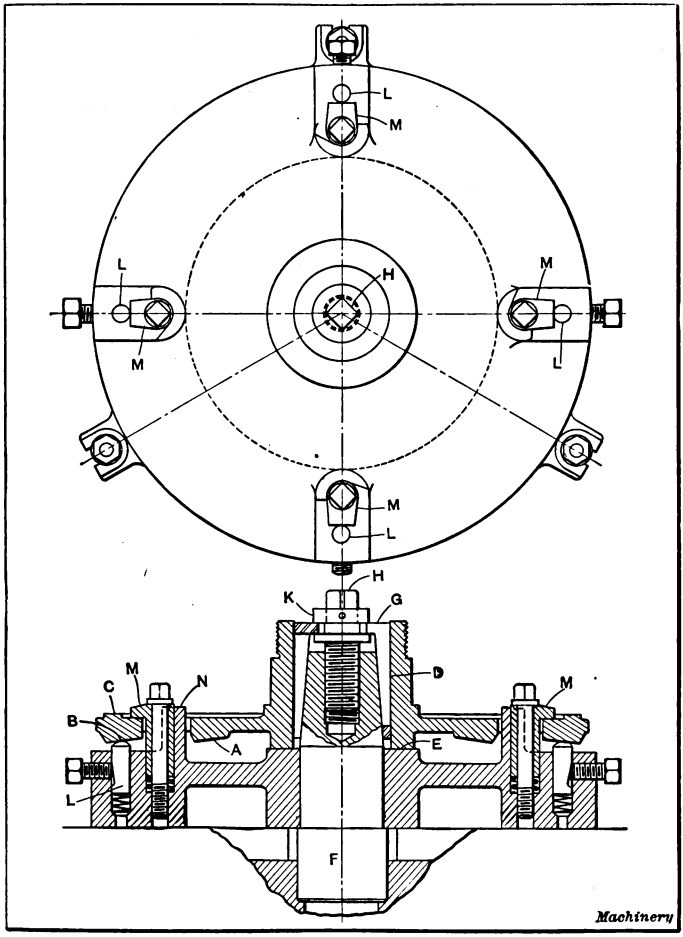


Fig. 14. Vertical Boring Mill Fixture for Special Design of Bevel Gear

ing of the rings as they were being cut off on an automatic machine. A new method was therefore devised by which the "ring pots" were bored and turned eccentric and then taken to a vertical milling machine where they were placed on the arbor shown in Fig. 15. The

fixture of which the arbor forms a part is located in the center of a circular milling table by the stud *B*, and is secured to the table by means of the three screws *A* in the T-slots. The stud is tapered at its upper end to receive the split bushing *D*, and is secured by the pointed screw *C* and prevented from turning by the key *E*. The bushing was saw-cut in six places to permit expansion, and was also counterbored in three places at its lower end to make a pocket for the coil springs *F*. These springs tend to make the releasing of the split bushing easy after the work has been done. The collar *G* bears on the upper

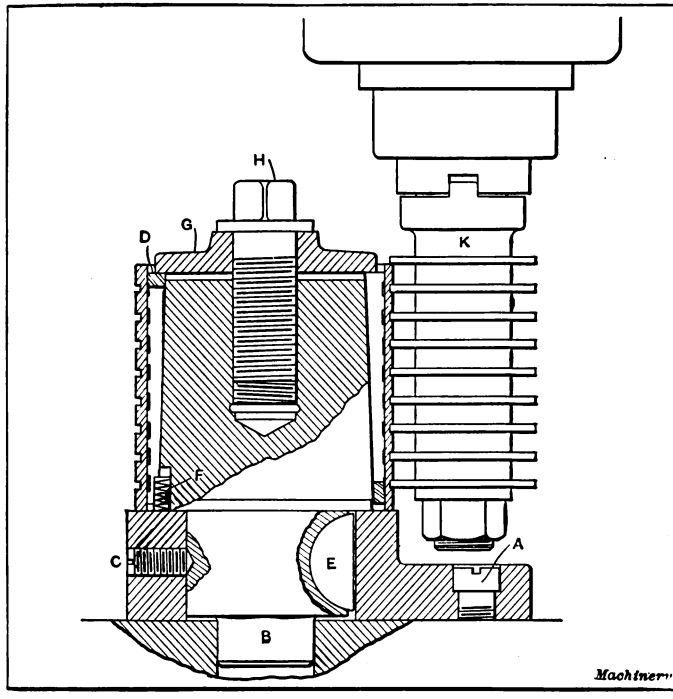


Fig. 15. Expanding Arbor for holding Casting while Gang-sawing Packing Rings

portion of the split bushing *D* and is operated by the screw *H* which is threaded into the body of the arbor.

A special arbor *K* in the spindle of the vertical milling machine was arranged with a gang of saw cutters properly spaced for the correct width of ring. As the table is revolved by power feed, the gang of cutters produce a set of nine clean and unbroken rings. It may be noted that the split bushing is relieved on its periphery at the points where the cutters pass through the work, in order to avoid dulling the cutting edges on the hardened surface. This fixture was made up very carefully and proved very satisfactory. To the best of the writer's knowledge, it is still in use although made over six years ago.

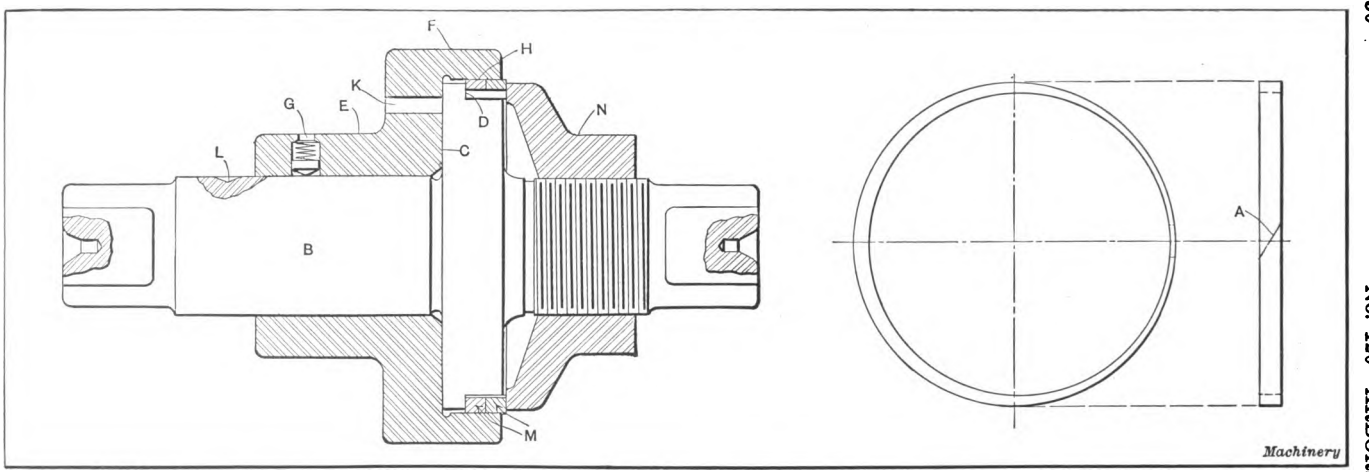


Fig. 16. Arbor for compressing and holding Split Packing Rings while grinding

A Grinding Arbor for Piston Rings

The right-hand view, Fig. 16, shows an eccentric piston ring for a gas engine which has been bored, turned eccentric, ground parallel on the sides and split apart at the point *A*. The arbor shown to the left in the same illustration was used for grinding the periphery to make it perfectly cylindrical after it had been split and closed up at *A*. The body of the arbor *B* is of tool steel with generous centers in each end. These centers were lead-lapped after hardening and before grinding the cylindrical portion. The faces *C* and *D* are also carefully ground. The locating collar *E* is of tool steel, hardened and ground to a very close running fit on the arbor and at the point *H* where the rings fit. The portion *F* is knurled to give a good gripping surface for the hand when pulling back the sleeve. The spring detent *G* serves to hold the sleeve in position when it is pulled back out of the way for grinding. The hole *K* is an air hole and is very essential, for as the parts are all very closely fitted the

suction is so great that it is almost impossible to pull back the sleeve unless this relief hole is drilled. A longitudinal groove along the arbor would answer the same purpose, but is more likely to catch dirt and thus cause trouble. The nut *N* is of tool steel, has a coarse pitch thread and is made hexagon at the small end. The faces which bear against the rings are ground parallel with the thread. When in use, the nut is slipped back out of the way and the two rings *M* are sprung into place inside the locating collar after which the nut *N* is brought up against the rings and tightened. The locating collar is then pushed back out of the way, until the detent snaps into place, and the work is then ready for the grinding operation on the periphery. Arbors of this type are in daily use in nearly all of the automobile factories in this country.

The various types of arbors and fixtures illustrated and described in this article cover representative work of nearly all kinds, and may be modified to suit almost all possible conditions whether they affect the work part, the machine, or both.

CHAPTER III

WORK-HOLDING ARBORS AND METHODS FOR TURNING OPERATIONS

The developments in the design of machine tools during the last ten or fifteen years have brought these machines to a high degree of perfection. Many are provided with features which make great precision possible, and a workman who understands how to get the most out of one of these modern machine tools can produce very accurate work. It should be remembered, however, that no matter how accurate and how well adapted to rapid production the machine may be, if the methods of holding the work are not equally well thought out there is comparatively little gained. As a matter of fact, this point is neglected in a great many machine shops. In a few instances, we find planning departments and efficient tool-designing departments where the methods and appliances to be used in manufacturing are carefully considered. In the majority of shops, however, the workmen, or at least the foremen, are left to devise for themselves the methods by which the work is to be held in the machines. In the few cases where the workman is unusually ingenious, this may be of advantage, but it is seldom possible for the man at the machine to consider both the accuracy required and the rapidity of production with anything like the care that can be done by a designer especially detailed to do this work.

Therefore, it is becoming generally recognized that in order to take advantage of the full capacity and adaptability of modern ma-

chine tools, it is necessary that the work-holding and machining methods be worked out by designers of equal ability to those who actually design the machine. In the following a few methods will be shown for holding different classes of work for turning and facing operations in the lathe. The arbors and devices shown were designed at the Jones & Lamson Machine Co., Springfield, Vt., for use in the Fay automatic lathe; but as far as the methods for holding the work are concerned, they may be employed with equal advantage in any engine lathe, and are therefore capable of wide application. The tooling arrangements shown in each case are, of course, especially adapted to

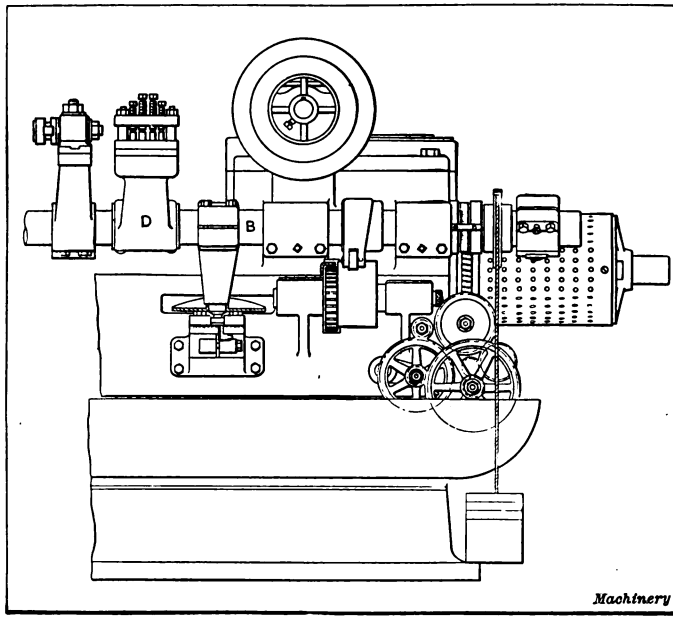


Fig. 1. Rear View of Head End of Fay Automatic Lathe

the Fay automatic lathe with its front and rear tool-holders, but by means of a special tool-block many engine lathes could be rigged up to perform the work in a similar manner. These tooling arrangements will probably suggest other machining methods.

Principles of Arrangement of the Fay Automatic Lathe

In order to make the following article intelligible in so far as the arrangement of the tools is concerned, it will be necessary to refer briefly to the construction of the Fay automatic lathe. The line engraving Fig. 1 shows a rear view of the head end of the machine; Fig. 2 shows a sectional view The main or work-spindle is driven by worm gearing from a cone pulley mounted at right angles to it. A series of cams is provided for controlling the cutting tools, and by means of a clutch mechanism operated by adjustable dogs, the cam-

shaft may be given a slow feeding movement or a rapid idle movement over any portion of the periphery of the cam. Two heavy bars, *A* and *B*, extend the full length of the machine and on these the various carriages and tool-holders are mounted. Each of these bars is controlled by a cam both as regards the longitudinal and the rocking movement about their axes. The rocking movement of the front tool-holder *C* is caused by templets or cam surfaces on the slide or former bar at the front of the bed on which the outer end of the carriage rests. These templets may be given any desired shape which will be copied by the tool as the carriage is fed longitudinally. The car-

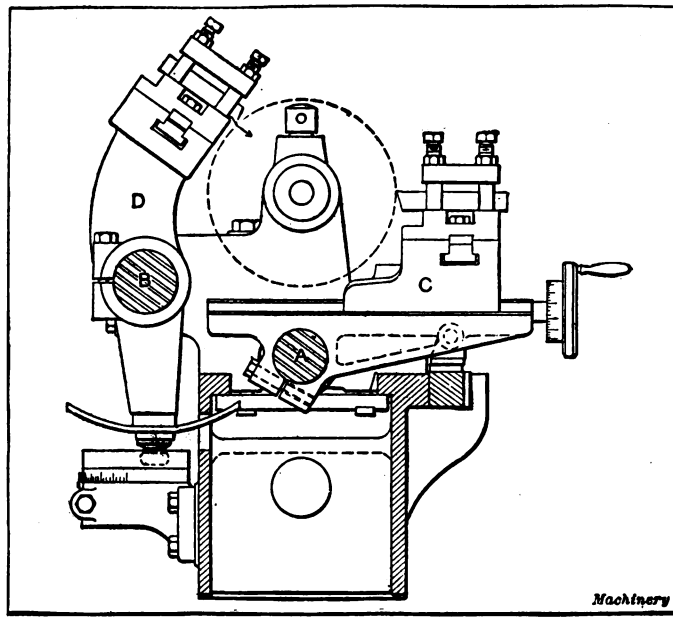


Fig. 2. Cross-sectional View of Fay Automatic Lathe

riage may also be held stationary and the former bar carrying the templet may be fed to the right or left, thereby causing the tool to feed directly in or out at right angles to the axis of the work. The main tool bar is operated longitudinally by an internal cam surface within the cam drum shown to the right in Fig. 1, and the tool slide at the rear is rocked by a cam beneath the headstock. It will be understood from this description that the front tool-block *C* is especially adapted to straight turning, taper turning and forming operations, while the rear tool-holder *D* is intended for operations requiring the tool to be fed in toward the center of the work after which, of course, the tool-bar can be fed longitudinally for ordinary straight turning operations.

Arbors for Holding Bushings made in Halves

The arbor shown in Fig. 3 is used for holding the type of half-bushings illustrated while turning the outside. When performing this operation, it is necessary that the bushings be so held that the parting line comes exactly in the center, so that the two halves are interchangeable. At the same time, they must be held so that the outside will be true with the inside, which has already been finished by a formed convex milling cutter. When the inside has been finished, the two halves are clamped to an arbor and the ends are finished to a beveled surface by a hollow mill. The half-bushings are then ready to be placed on the arbor shown in Figs. 3 and 5, where they are held in place by beveled collars slightly corrugated on the tapered surfaces to form an effective drive. By holding the bushings in this manner

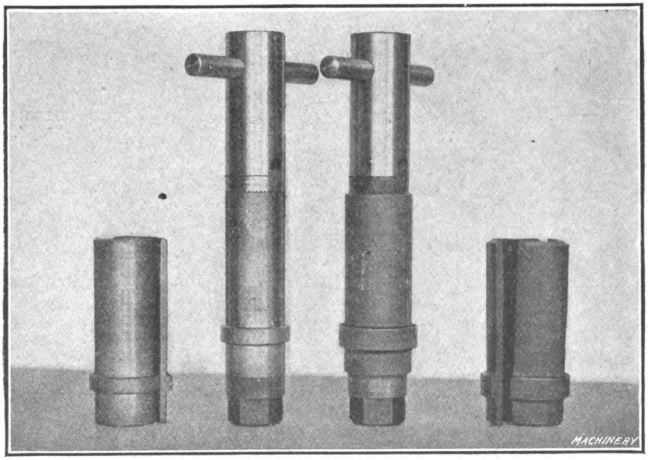


Fig. 3. Half-bushings to be machined and Arbor used for holding them while turning Outside

the whole of the outside can be finished at one setting. The rear tool-block carries the roughing tools and is first fed inward in the direction of arrow *A*, Fig. 5, and then to the left in the direction of arrow *B*. The roughing cut is divided between the tools *C*, *D*, *N* and *O*, so that the tool slide needs to feed from *E* to *F* only in order to complete the roughing cut. The tool *N* roughs out the top of the shoulder on the bushing, while the tool *O* roughs out the part of the bushing to the right of the shoulder.

The finishing tools are held in the front tool-holder. Tool *H* is first fed in the direction of arrow *G*, finishing one end of the bushing, and then tool *K* is fed in the direction of arrow *L* to finish the other end of the bushing; at the same time, tool *M* finishes the collar or shoulder shown. The roughing is entirely completed before the finishing cut begins. The finishing cut on the long surface to the left on the bushing is done by one tool *K* and not by two tools as in the case of the roughing cut, because if two tools were used for finishing it would be

difficult to avoid a slight mark on the turned surface at the point where the two cuts meet. Fig. 4 shows the work and tools as arranged in the machine.

In Fig. 6 is shown an arbor used for holding a tapered bushing while finishing the outside; the bushing is shown in Fig. 7, and Fig. 8 shows the work and tools sets up in the machine. In this case the hole in the bushing, which is made in halves as in the preceding case, is rough. The joint between the two halves must, however, come exactly in the center of the finished bushing so that the two halves may be interchangeable. The first operation is to plane the joints; then the two halves are clamped together and the ends are finished by a hollow mill to form a bevel bearing for the clamping collars of the arbor. When milling the ends, the joint must be held central in

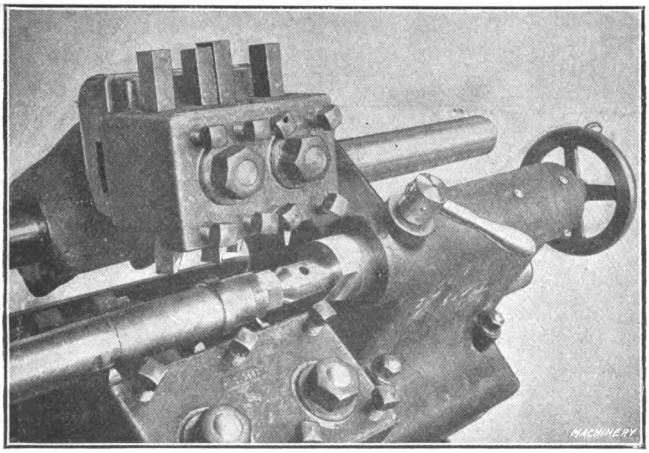


Fig. 4. Tools illustrated in Detail in Figs. 3 and 5 set up on Fay Automatic Lathe

a jig especially designed for the purpose. The half-bushing is then clamped on the arbor shown in Fig. 7, the beveled surfaces of the collar and shoulder holding it true. Fig. 6 shows the arrangement of the roughing tools, the arrows indicating the direction in which they are fed. The front and rear tools are in action simultaneously. The front tools are guided by a taper former on the former bar. In the roughing operation the small surface at *A* will, of course, be turned on a taper, but this will be corrected by the finishing operation, the tooling arrangement for which is shown in Fig. 9. In this case the tools in the back tool-holder finish the short taper on the shoulder and the top of the projection. The long taper surface of the bushing is finished by the tool held in the front tool-holder. Arrangements are made for relieving the tool on the return.

Fig. 10 shows another tapered bushing made in halves, which is turned on the outside before the inside is finished. Here the ends are not finished because other means are available for holding the

work so as to locate the joint in the center of the finished bushing. There are lugs on the inside of one of the half-bushings, which bear against shoulders on the arbor, as shown by the section to the left. After the two halves are finished by planing, the half provided with the lugs is first placed on the arbor so that the lugs bear against these

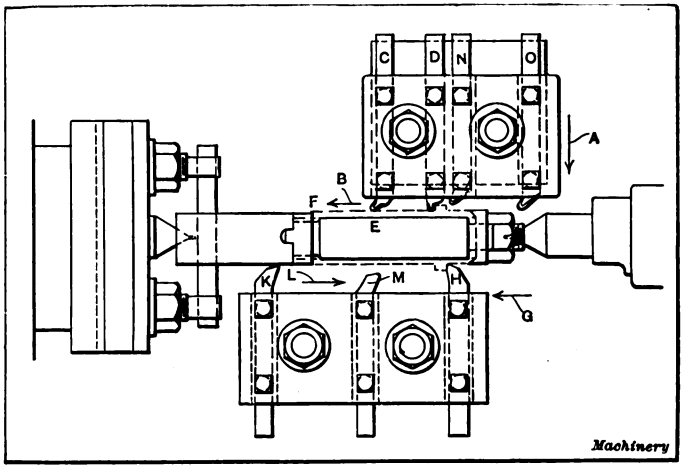


Fig. 5. Tool Arrangement for turning Half-bushings shown in Fig. 8

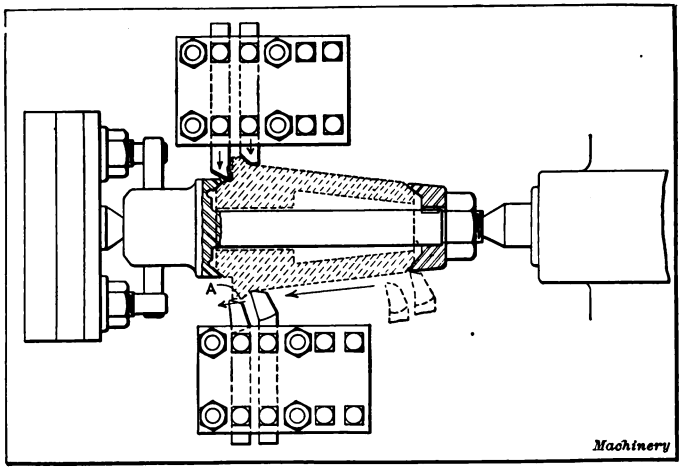


Fig. 6. Method of holding Tapered Bushings shown in Fig. 7

shoulders, which insures a correct location. As the ends are rough, the clamping arrangements must be made to take care of any adjustment necessary to provide a full bearing. A bushing *C* is therefore provided within which slide two half-bushings *D*, operated by adjusting screws. By means of these screws each half of the bushing to be turned can be clamped tightly against the collar at the other end of

the arbor; at the same time the joint in the center will be held in correct relation to the center of the arbor. The roughing cut is divided between the two tools in the rear tool-holder and the finishing is done by the tool in the front tool-holder. Only the short surface from *E* to *F* is finished.

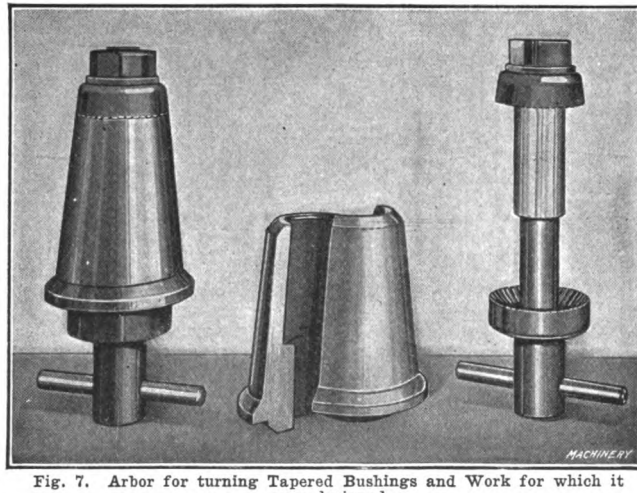


Fig. 7. Arbor for turning Tapered Bushings and Work for which it was designed

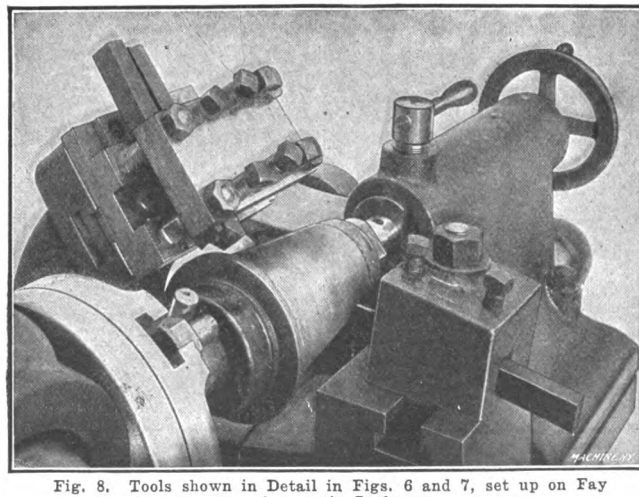


Fig. 8. Tools shown in Detail in Figs. 6 and 7, set up on Fay Automatic Lathe

Holding Work with Square Holes

A piece of work with a square broached hole by which the piece is held on a square arbor is shown in Fig. 11. In this case the cutting is all done in one direction so that it is unnecessary to provide for clamping the work for endwise motion. An illustration of the piece

of work and the arbor, also showing the work in place on the arbor, is given in Fig. 12. The tools, as inserted in their respective holders, are shown in place on the machine in Fig. 14.

Fig. 13 shows a simple method for holding a gear blank with a square hole. The hole in the blank is first bored, after which the

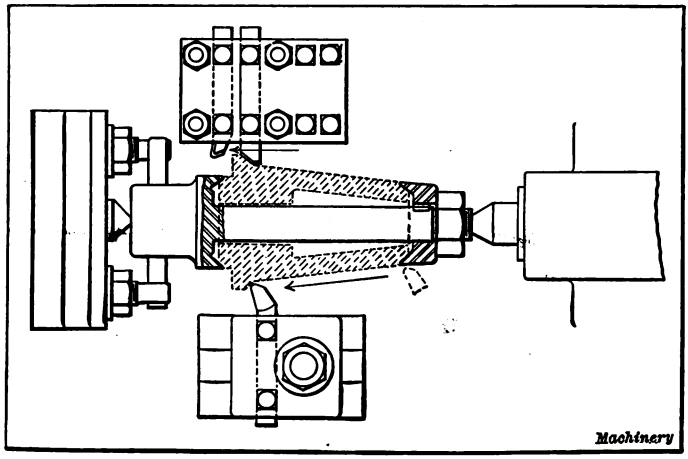


Fig. 9. Finishing Tool Arrangement for Bushings shown in Fig. 7

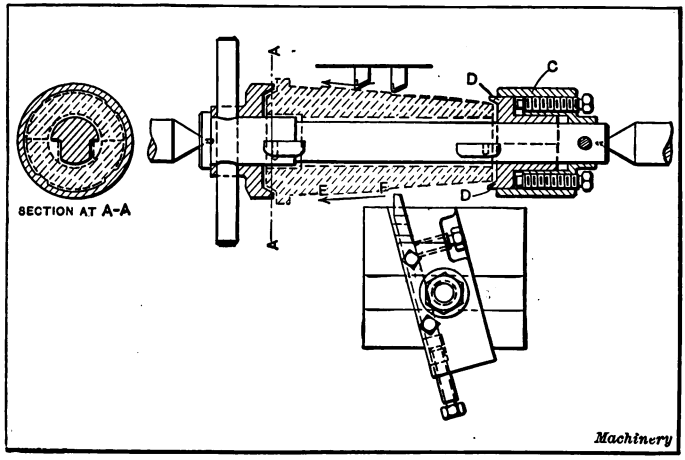


Fig. 10. Arbor for holding Tapered Bushings with Rough Ends

piece is roughed all over except on the large diameter and on the face next to it, as it is held by these surfaces in the turret lathe. Then the hole is broached, two keyways being provided at the same time, after which the piece is placed on the arbor, the keys being driven in just tight enough to hold it in place. The tooling arrangement used for finishing the surfaces is shown in the illustration.

When a piece of work is to be finished on the Fay automatic lathe, or in any lathe with multiple tools and fixed stops, it is necessary that the endwise location of the work be always the same; hence when

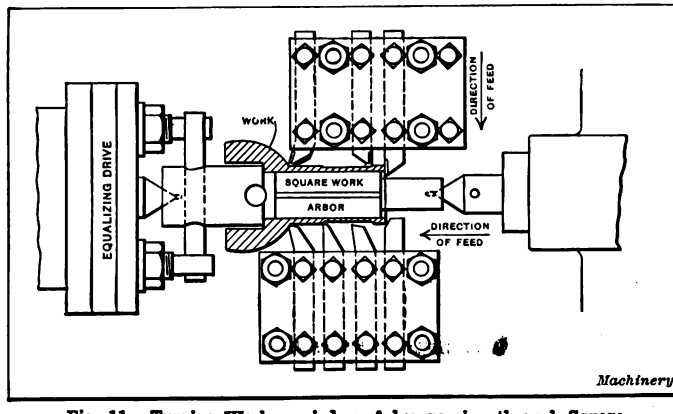


Fig. 11. Turning Work carried on Arbor passing through Square Broached Hole

work with a round hole is to be finished, it cannot be held on an ordinary arbor with a slight taper unless the hole is so accurately finished that the piece will come to a driving fit at a given place on

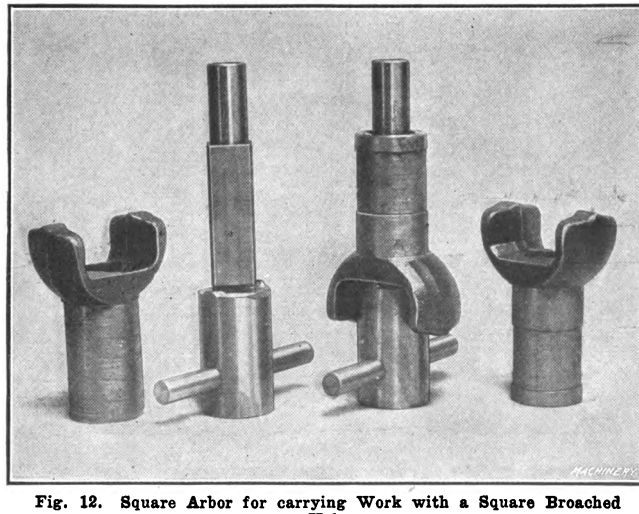


Fig. 12. Square Arbor for carrying Work with a Square Broached Hole

the arbor, in which case the point to which the work is to be driven may be determined by means of a simple gage which acts as a stop. As a matter of fact, some firms make it a point to machine the holes in work of this kind so accurately that the work can be driven onto

an arbor and come to a driving fit at a given point. This can almost always be done with bronze bushings, as there is enough elasticity in this material to permit the pieces to be forced down to a certain position. With this method of holding, both ends of the work can be faced, as there are no clamping arrangements to obstruct the path of the tools.

Holding Work by means of Expanding Bushings

One of the simplest methods for holding work with a finished hole is by means of expanding bushings. This method makes it possible to chuck the hole in a drill press and still hold it at a given position on an arbor without obstructing the ends of the work, and in such a way that both ends of the work can be faced. In the case shown in Fig. 15 the hole was too long to fit a split bushing the entire length, as the thickness of the bushing would have been rather excessive at one end, or else the taper would have had to be made too small; therefore part of the arbor is turned straight and fits the hole in the gear blank to be turned. In order to insure that the piece be placed in the same position longitudinally each time, a gage bushing, an end view of which is shown in the lower left-hand corner of the illustration, is used to gage distance *A*. The piece of work is dropped onto the arbor and secured loosely against the gage; then the gage is withdrawn and the nut is tightened to hold the work firmly in place. The arrangement of the tools for finishing this piece is clearly indicated in the illustration.

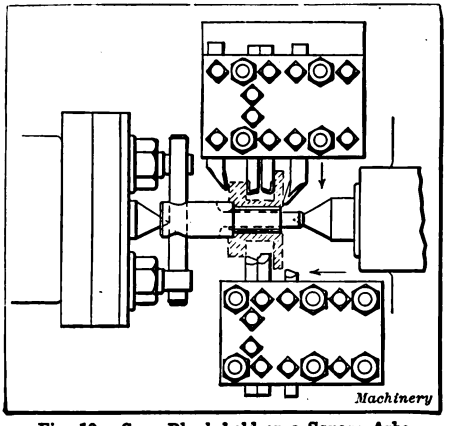


Fig. 13. Gear Blank held on a Square Arbor

In Fig. 16 is shown another example of an arbor for clamping work by means of a split bushing. The work here shown is an armature bearing box. No gage is necessary in this case, as the work is located by a shoulder at one end of the arbor, only one end of the work being faced off. The roughing is done by the tools in the rear tool-holder and the finishing by the tools in the front holder. Another interesting method of holding work while machining is shown in Fig. 17. The work here shown in position on the arbor is a shrapnel shell. The work is threaded on the inside at one end and can thus be screwed onto a threaded portion of the arbor. The end of the arbor is split and provided with an expander. The rear tool slide holds the roughing tool which faces the end, and also a forming tool which comes into a surface free from scale that has been roughed off by one of the

tools in the front slide. The direction of the cut of the tools in the front slide, first inward, then parallel, and then slightly outward, is shown by the arrow. Fig. 18 shows the arrangement of the tools for roughing and finishing the tapered end of the shell and for knurling a groove at the closed end. In this case a special grooved former must be used in place of the taper attachment of the machine at the rear. When the front tool at the left has completed its cut the finish-

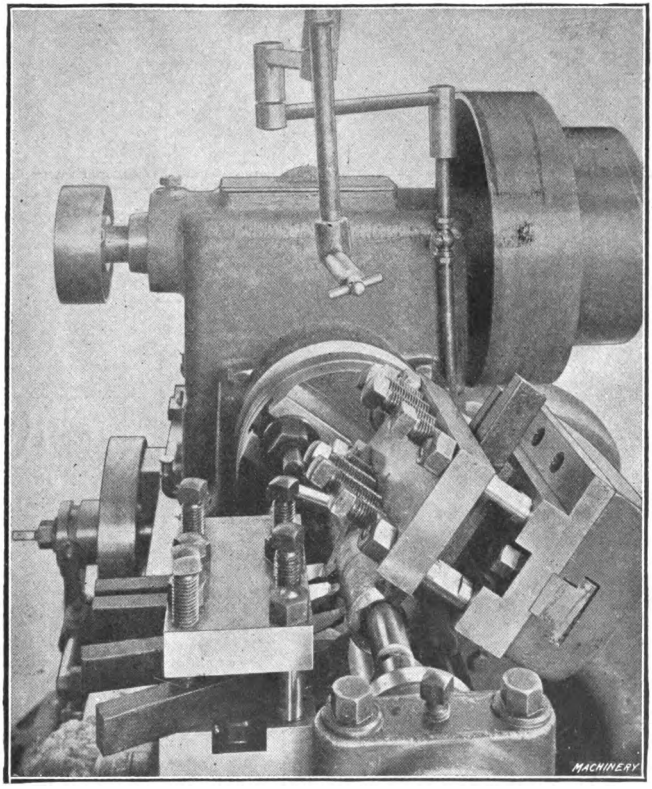


Fig. 14. Turning Work carried on a Square Arbor in a Fay Automatic Lathe

ing tool-holder drops in, permitting the tool to the right to perform the knurling operation. In this case a former is clamped to the former bar of the machine.

Supporting Thin Work from the Inside

The most interesting holders for work that is to be machined in the lathe are, perhaps, those that are arranged to support thin work from the inside. In Fig. 19 is shown one example of a piston held by an equalizing arrangement. This arrangement is applicable only to pistons which are not to be ground. The usual method is to bore a

hole for a short distance inward at the end of the piston and then drill the wrist-pin hole. The bored portion is used for locating the work in position by means of a stud through the wrist-pin. The method shown in the present illustration, however, permits the work

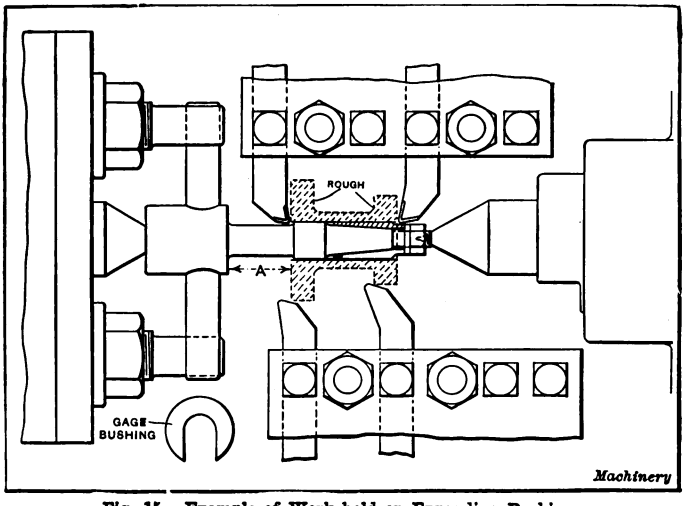


Fig. 15. Example of Work held on Expanding Bushing

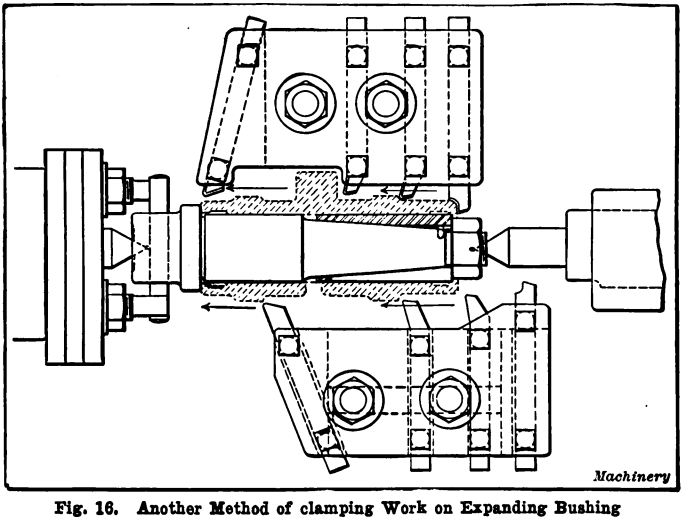


Fig. 16. Another Method of clamping Work on Expanding Bushing

to be done in one operation without any counterboring, and with the assurance of an even thickness of metal all around the piston. One end of the piston is centered in a centering machine. If the piston is heavy it may be held by the outside during this operation. If the metal is thin, it is preferable to center it with reference to the inside,

holding the work in a jig like the fixture used in the machine. The holding device consists of three plungers *A* at each end of the piston, which slide in slots cut in the head of bolt *B* and in collar *C*, and which thus both center the work and support it on the inside. In the case of small pistons only two plungers are used at the closed end,

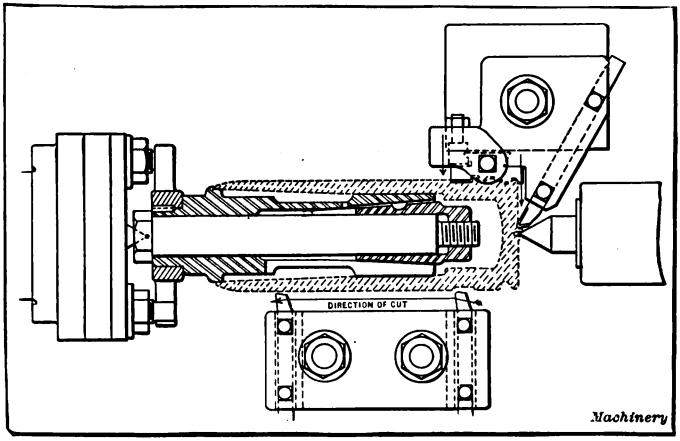


Fig. 17. Combination Threaded and Expanding Arbor for holding Shrapnel Shell in Lathe

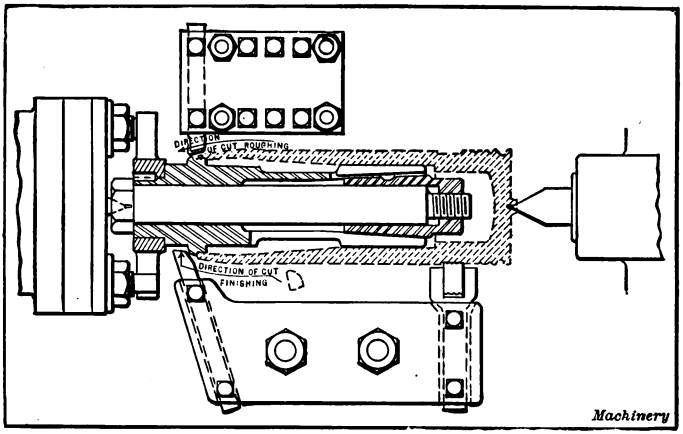


Fig. 18. Tool Arrangement for turning Shrapnel Shell Point and knurling Groove at Closed End

because there is not enough room for three on account of the bosses for the wrist-pin. The bolt with the tapered slot is tightened by means of a nut having a slot in it, which can be reached from the end of the arbor when the fixture is taken out of the machine, by means of a special screwdriver. The tooling arrangement shown in the illustration is that provided for roughing the piston. The two tools in the

front holder divide the roughing cut between them so that the feed motion needs to be only one-half of the length of the piston.

Fig. 20 shows a method used for supporting the overhanging rim of a long pulley. In this case the pulley is centered by the hole which fits the arbor, and the support must simply act as an equalizer. As will be seen, two floating collars *A* and *B* are provided which are tapered on one side. This tapered side bears against pins *C* and *D*. As the collars are perfectly free to locate themselves with relation to the arbor, it is evident that the pressure on the pins (of which there are three for each collar) will be the same, and there will be no tendency

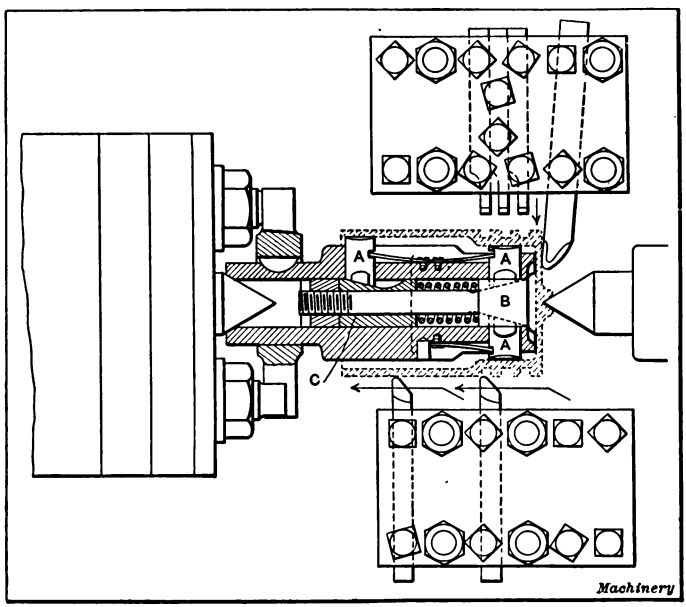


Fig. 19. Arbor for holding Pistons to be turned

to throw the work out of center, but to merely support it with equal pressure at the six bearing points.

Holders for Two Pieces of Work

In many instances it is possible to hold two pieces on the same arbor, thus practically cutting the time of machining in half. The simplest illustration of this is probably that shown in Fig. 21, where two gear blanks, which have been faced on one side and have had the holes bored, are clamped together and faced on the other side and turned on the outside. The arrangement of the tools is of interest; the arrows shown give the direction of the feed and indicate the method of procedure. Fig. 22 shows another case where two pieces held on the same arbor are machined at the same time. A spacer is provided between the two pieces so as to locate the one to the right in

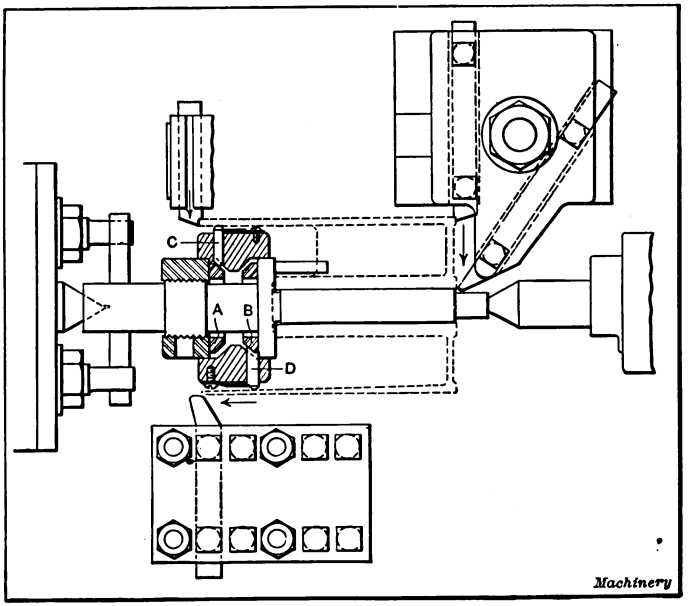


Fig. 20. Method of supporting Pulley from Inside while turning

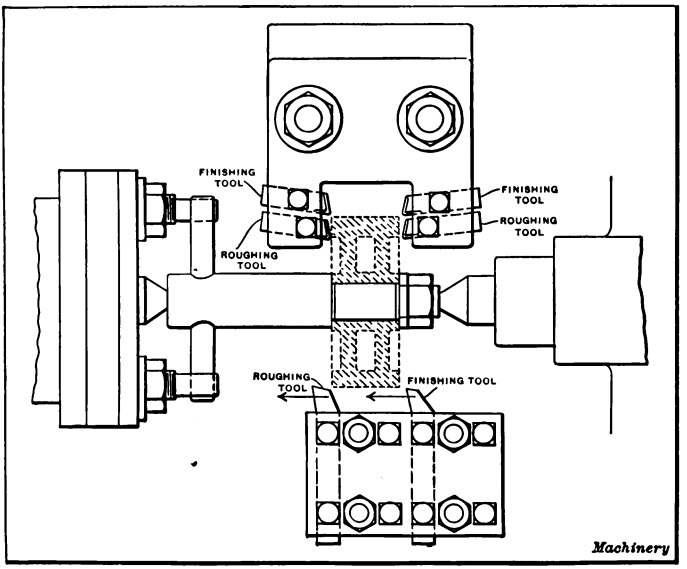


Fig. 21. Example of Arbor designed to hold Two Pieces of Work at One Time

position, the one to the left being located against a shoulder on the arbor. In order to use this arrangement for location, it is necessary

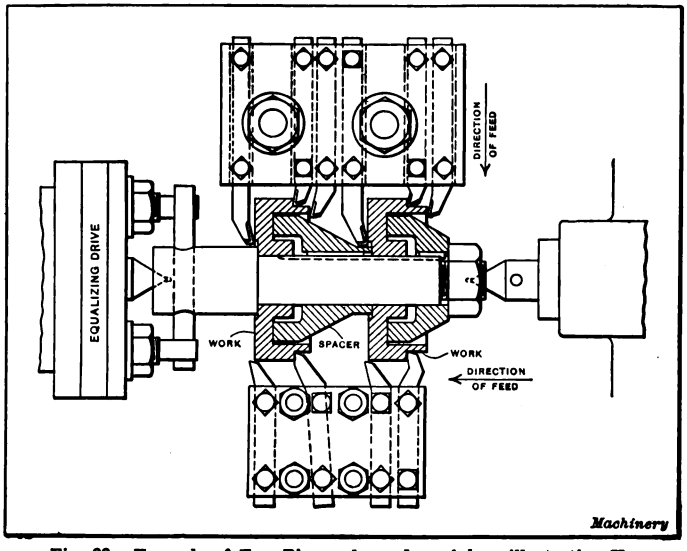


Fig. 22. Example of Two Pieces clamped on Arbor, illustrating Use of Spacer

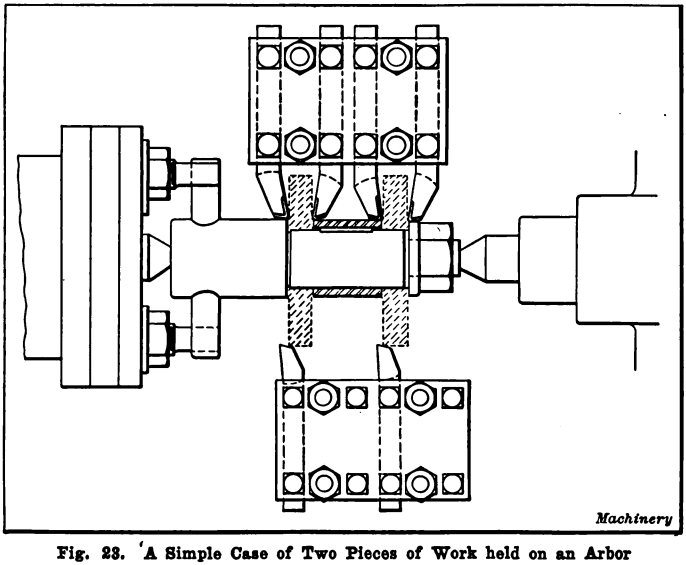


Fig. 23. A Simple Case of Two Pieces of Work held on an Arbor

for the work to have shoulders finished on two sides and also that the finishing be done accurately enough so that it can be used for locating

the two pieces. In this case both the clamping collar and the spacer are keyed to the arbor to make the drive more positive.

In Fig. 23 is shown another case of clamping two pieces using a spacer between them. It is evident that if the two sides of the hubs of the gear blanks had not previously been machined, this method could not be used as the gear blank to the right would not come in an accurate position to permit being machined by the tooling arrangement indicated.

In Fig. 24 is shown still another example of holding two pieces by means of a spacer. Here the roughing and finishing are done at the same time. The tools in the rear and front holders operate simultane-

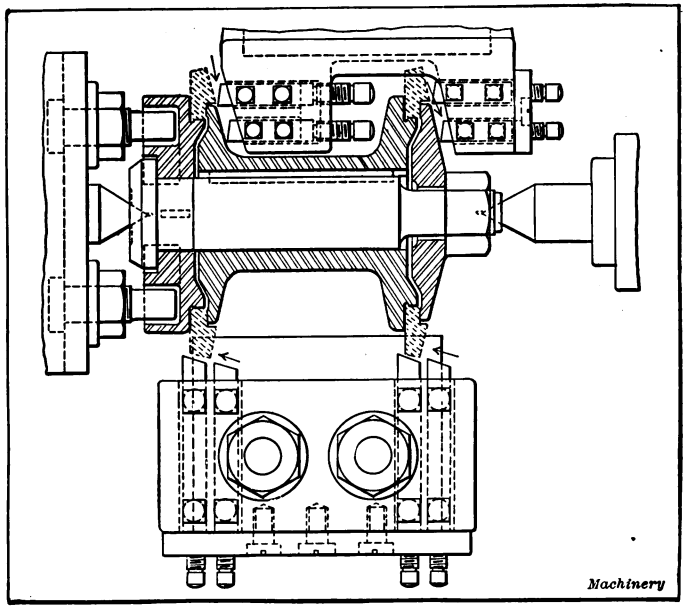


Fig. 24. Another Example of Use of Spacer between Two Pieces

ously, the taper attachment being used for the rear holder. A taper former is used on the former bar for the front tool-holder. Fig. 25 shows an especially interesting arrangement for holding two pieces and for supporting the thin walls of the bushings while machining. In this case the ends and the inside of the bushing are rough. The only difficulty that was met with was to machine them without distorting them on account of the thinness of the metal. The bushings are both centered and supported by the rough inside surface. For this purpose bushings *B* are provided on the arbor. These bushings hold plugs *C* which are prevented from falling out of their seats by springs when the pieces to be machined are to be removed from the arbor. The arbor itself is provided with three flat spots or bearings, as shown in the sectional view at the top. These act as cam surfaces when the

arbor is turned and force the plugs outward, thereby centering and supporting the work on the inside. This arbor shows a different method than those shown in the previous examples for holding two pieces at once. Here the middle portion of the arbor is solid and

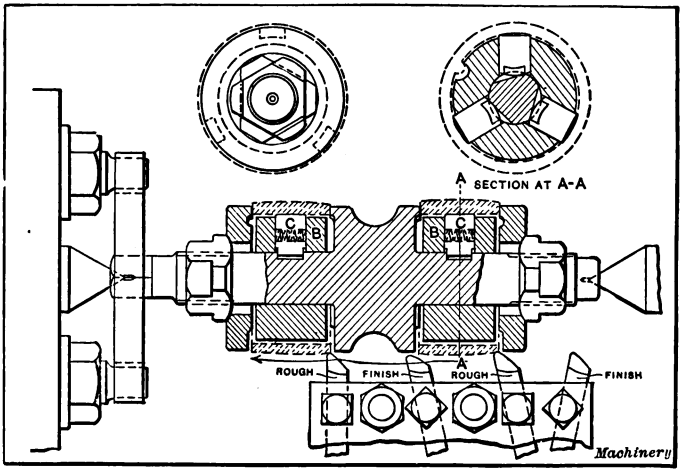
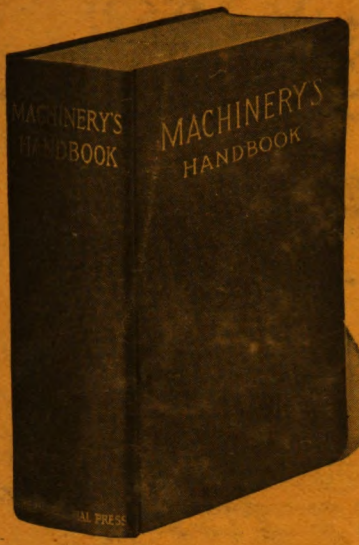


Fig. 25. Arbor for holding Two Pieces of Work which must be supported from the Inside

provided with three bearing points on each side for the work. Then collars are provided at each end of the arbor with nuts for clamping the work. One disadvantage is present with this arbor. The dog at the driving end must be removed to take off the pieces nearest to the head. In practically all the other cases shown a driving pin driven into the arbor can be used, as the work is removed in the other direction.



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